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ABSTRACT

The purposes of this study were to determine if test stimulus was a member of the memory set and if items in an interactive image held in short term memory (STM) could be scanned simultaneously. In experiment one, 50 university subjects compared a test word with a set of one to three words held in STM. The rate of STM search was obtained by measuring reaction time (RT) under four instructional conditions: subvocal repetition, separation imagery, interaction imagery, and sentence generation. The results indicated that RT was a linear function of memory set size in the interaction imagery condition. All other conditions also yielded a linear increase in RT with set size. In experiment two, memory set and test stimuli were both pictorial. Three groups of subjects compared items in the memory set and test stimuli. There were three experimental conditions: control--two pictured objects side by side but not interacting; provided interaction--two objects shown interacting with one another or overlapping; and subject generated interaction--subjects were given the same stimuli as the control group but were to visualize some kind of interaction between the pictured objects. The results indicated that paired associate scores in both imagery groups were superior to those in the control group. (WR)

Technical Report No. 317

INTERACTIVE MENTAL IMAGERY AND SHORT-TERM MEMORY SEARCH RATES FOR WORDS AND PICTURES

Report from the Project on Children's Learning and Development

by Stephen Marshall Kerst

Joel R. Levin
Principal Investigator

Wisconsin Research and Development
Center for Cognitive Learning
The University of Wisconsin
Madison, Wisconsin

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ABSTRACT

Independent groups of Ss compared a test word with a set of one to three words held in short-term memory (STM) to determine if the test stimulus was a member of the memory set. The rate of STM search was obtained by measuring reaction-time (RT) under four instructional conditions: (1) Subvocal Repetition, where Ss repeated the words in the memory set to themselves, (2) Separation Imagery, in which Ss generated a separate covert visual image of the referent of each word, (3) Interaction Imagery, in which Ss imagined a scene where the referents of the words were interacting, and (4) Sentence Generation, where Ss composed an active covert sentence using the words in the memory set.

It had been predicted from the results of another experiment (Seamon, 1972) that items combined in an interactive image in memory could all be compared at once to the test stimulus, so that reaction-time would remain constant in spite of an increase in the size of the memory set. Serial comparisons were expected in the Repetition and Separation Imagery conditions, while the type of comparison used in the Sentence Generation condition was not predicted. This condition was included to test the possibility that verbal and visual interactions would have the same effects on STM search. Contrary to Seamon's (1972) results, RT was a linear function of memory set size in the Interaction Imagery condition. This finding indicates that comparisons between the stimuli in the memory set and the test stimulus were not completed simultaneously since extra time was required for additional comparisons.

All other conditions also yielded a linear increase in RT with set size, which is usually found in this paradigm (Sternberg, 1969). Seamon's (1972) failure to detect this effect in an interaction imagery group was discussed in terms of a lack of statistical power rather than in terms of the properties of the mental image.

In order to permit a stronger test of the hypothesis that items in an interactive image held in STM could be scanned simultaneously, a second experiment was conducted in which the memory set and test stimuli were both pictorial. Only memory set sizes one and two were used.

Three groups of Ss compared items in the memory set and test stimuli. In the Control condition, memory set stimuli for set size two consisted of two pictured objects which were side by side but not interacting. In the Provided Interaction condition, the two objects were shown interacting with one another or overlapping. In the S-generated Interaction condition, Ss were given the same stimuli as the Control group but were told to visualize some kind of interaction between the pictured objects. An unexpected paired-associate recall test based on the set size two items was given after the memory search task was completed. Since interaction imagery is known to facilitate paired-associate learning (Paivio, 1971), superior scores in the S-generated Imagery group could be taken as evidence that Ss were complying with the mnemonic instructions. Paired-associate scores in both imagery groups were superior to those in the Control condition, which indicates that Ss attempted to follow instructions in the S-generated group, and that some mnemonic process was involved in the Provided Imagery condition.

Even though visual imagery apparently united the pictured pairs of objects in long-term memory (as indicated by paired-associate recall), it did not affect the nature of the STM search, since RT was a linear function of set size in all conditions. The possibility was discussed that a simultaneous scan of STM would not be obtained when the test stimulus constituted only part of a compound memory representation. That is, an image of two interacting objects would have to be scanned one object at a time if the test stimulus were a single picture of an object. An experiment designed to test this hypothesis was described.

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Chapter I

INTRODUCTION

Over 100 years ago Donders (1868) proposed that mental operations could be characterized by the time required to complete them. In this view complex processes could be broken down into simpler ones, and the time required for a complex mental process was seen as the sum of the times required to execute each simple one. The empirical method which accompanied this perspective involved the construction of a series of tasks, where each task was designed to involve just one more mental operation than the previous one. The time required for this additional operation could be found by noting the time difference between two tasks which presumably differed only in that one contained an additional operation not found in the other.

Donders (1868) used three such tasks: detection, discrimination, and choice. In the detection task, _S_ simply responded as quickly as possible when a single stimulus, such as a light, was presented. The discrimination task had the additional requirement that _S_ respond only to one of several stimuli. In the choice task, a different response was to be made to each stimulus, thus adding the operation of choosing among responses to the discrimination task. By subtracting detection task time from discrimination task time, one found the time required for the operation of discrimination itself. Similarly, by subtracting discrimination task time from choice task time, the duration of the response-choice operation was obtained. A fundamental criticism of Donders' (1868) subtraction method is that it requires a new task to be devised for each additional mental operation (Posner, 1973). The assumption that a new task is the same as a previous one except for the addition of one operation is highly vulnerable. Implicit in this proposition is the assertion that there is no interaction among operations; i.e., additional operations do not change previous ones or combine with them in some way other than simple addition.

The "one additional operation" assumption can be avoided if one restricts the analysis to one task and decomposes task times numerically. In a visual search task Neisser (1963) studied the effect of the serial position of a target item on the amount of time required to search a list for a particular letter. In this task, a timer was started simultaneously with the presentation of the list and was stopped when S turned a switch to indicate that he had found the target letter. Neisser (1963) was concerned specifically with the rate of search, i.e., the average amount of time required to determine whether an item in the list matched the pre-designated target.

In order to separate the rate of scan from the time required to plan and execute the switch-turning response itself, the total time was broken down into two parts by graphing search time as a function of the serial position of the target item (i.e., the number of items scanned before a response is made). The intercept of this function reflects the time required to identify the target letter, choose a response and turn the switch, while the slope indicates only the amount of time required to compare one item in the list with the target. Any operation that would occur only once during the entire search process regardless of the number of items to be scanned would affect only the intercept of the line, since the time taken for that operation would be constant for any length of search. This function is described by the equation for a straight line, $Y = aX + b$, where Y is the total time required for the entire scan-and-response sequence, a is the rate of search (slope), X is the number of items searched, and b is the amount of time needed to make the response (intercept). When this function is plotted, the intercept represents the hypothetical case where no items are searched (i.e., $X = 0$), but a response is made to a test stimulus.

In this model the time required for any operation which occurs only once during the entire sequence is reflected by the intercept (b), while the time taken by operations which occur each time an item in the list is scanned is indicated by the slope (a). For example, if the switch were changed so that it required twice as much time to turn it in order to signal a response and stop the timer, the intercept would be expected to double while the slope would remain unchanged. Similarly, if the stimuli were intensely illuminated so that Ss always blinked at the moment the list was first presented, the duration of this once-per-blink would affect the intercept of the function. On the other hand, the slope would increase if the letters were made less legible, so that each item to be scanned required a more lengthy inspection to determine if it matched the target. If this task were so difficult that S wiped his brow after scanning each letter, the average time required to wipe the brow would be added to the slope.

This method of separating total reaction time into component parts involves two key assumptions, both of which are subject to empirical test. First, it is assumed that the processes taking place during the intervals represented by the intercept and the processes whose duration is represented by the slope are independent of one another. The notion that different processes are represented by the slope and intercept can be tested by demonstrating that there are task variables such as those in the examples above which affect one term without affecting the other (Sternberg, 1969a, 1969b).[1]

The second assumption is like Donders' (1868) original assumption of additivity, namely that the time required for completion of a mental task is equal to the sum of the times required for each operation in the task. In Donders' case, the validity of this assumption rested on the possibility of constructing tasks which differed with respect to only one operation -- a tenuous proposition. In the present model, the additivity assumption is tested within one task where one attempts to predict total task duration from the slope and intercept values. The accuracy of this prediction is measured by the extent to which total search duration (Y) is a linear function of X, which is the number of items scanned in the example above. Experimenters using this paradigm typically report that about 95 per cent of the variance due to changes in X is "explained" by a linear trend. This model, where the intercept and slope components are added arithmetically, and where equal increments are added to search time by each additional item to be scanned, thus provides an excellent fit to the obtained data (Sternberg, 1967,

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[1] Testing the assumption of the independence of the slope and intercept values by calculating the correlation between them is not appropriate, since the slope is included in the formula which is used to compute the intercept (i.e., $b = \Sigma Y/n - a\Sigma X/n$, where a is the slope and b is the intercept of the regression line). As a result, a negative correlation is always found between the two values, even though they are independent in the sense that a given variable affects one but not the other.

1969a, 1969b).

Slope and intercept data can provide information in addition to supporting the assumptions of independent and additive operations. The linear relationship between the number of items scanned and the amount of time required to detect the target indicates that each inspection of a list item takes the same amount of time regardless of its position in the list. In other words, for the 50-item lists used by Neisser (1963), the search time per item remains constant regardless of the length of the search.

Since each additional item to be scanned increases search duration by a fixed amount, the search can be characterized as a serial process where items are scanned one after the other, rather than a parallel process where all items are scanned at once. This is hardly surprising in a visual search task where S directs his gaze downward along a column of letters. The slope as an indicator of rate of scan becomes a valuable clue to the serial/parallel processing question, however, when the search cannot be directly observed. This is the case when S is required to search his memory to determine if a particular item has been presented before in a recognition task (Sternberg, 1969a, 1969b).

The slope of the linear function can also be taken to indicate whether the search is exhaustive or self-terminating; i.e., does the search stop when the target is found (self-terminating) or are all the items in the list scanned before a response is made (exhaustive). Suppose that some lists do not contain the expected target letter while others do. If S is asked to respond "no" to lists which do not include the target letter and "yes" to those that do, one can compute separate slopes for "yes" and "no" responses. If the search is self-terminating, the time required for "yes" responses would be half that for "no" responses on the average, since only half as many items would have to be scanned as compared to the case where S must always search through the entire list before making a "no" response.

On the other hand, if the search were exhaustive, S would search the entire list whether or not the target had been found, and the "yes" and "no" response times would be equal. In the exhaustive search, search times would also be equal for items in all serial positions of the list. Since the process of determining if an item in the list is the same as the target takes place more than once in the entire search, the slope, rather than the intercept, represents the portion of time which would indicate either an exhaustive or a self-terminating search. Identical slopes for "yes" and "no" responses would thus indicate an exhaustive search, while "no" slopes would be twice as large as "yes" slopes if the search were self-terminating. Complications such as the possibility of a self-terminating search with a random order or starting point, where "yes"/"no" slope differences would not be obtained will be discussed later. The likelihood of parallel search processes which cannot be discriminated from serial processes by these methods will also be considered (Townsend, 1971).

Chapter II

REVIEW OF THE LITERATURE

Sternberg (1966, 1967a, 1969a, 1969b) took this method of separating search time from response time and used it to investigate the process of search for an item in short-term memory (STM), rather than the visual search for a printed letter on a page. In these experiments Ss were shown small sets (1-6 members) of numbers, or of non-symbolic stimuli, such as nonsense shapes or photographs of faces. After a short (2-3 second) retention interval, a test stimulus was presented, and Ss were asked to indicate whether the probe was a member of the original set. Presumably, some type of inspection, search, or scan of the representations of items held in memory is required to make this response.

The results paralleled those for Neisser's (1963) experiments in visual search. For all types of materials used, reaction time (RT) increased as a linear function of the number of items held in STM, which indicates a serial rather than a simultaneous search process within the capacity of STM (7 ± 2 items) the rate of search was similar and rapid (18-26 items per second) for all types of materials used. Slopes for "yes" and "no" responses did not differ, which indicates an exhaustive rather than self-terminating search. These results should be qualified since they are based on a simple STM recognition task. Long-term memory search processes appear to take more time and may involve additional operations such as the scanning of semantic categories when words are used as stimuli (Seamon, 1973). On logical grounds alone, it would seem unlikely that a simple exhaustive search is involved in long-term memory, since it would require that the entire contents of memory be searched before an item could be retrieved.

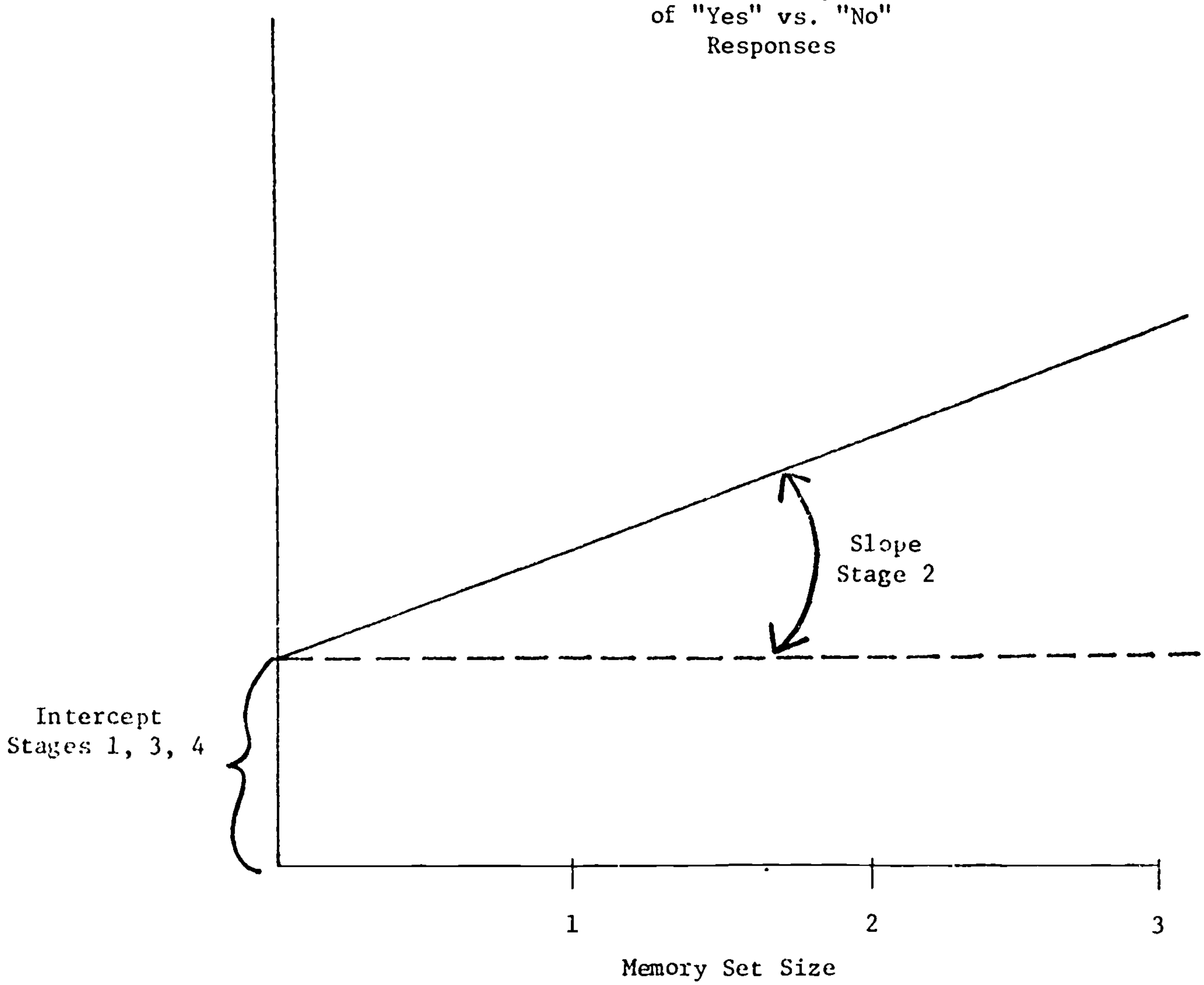
Does the STM search data support the assumptions of additivity and independence of stages of processing which are confirmed in Neisser's (1963) visual search model? Sternberg (1969a, 1969b) has found factors which differentially affect the stages represented by the slope and intercept of the RT function (see Figure 1). Making a digit test stimulus difficult to read by superimposing a checkerboard pattern on it increases the time required for perception or encoding of the test probe (stage 1, intercept) with no effect on the rate of scan (stage 2, slope) for practiced Ss. Making a "yes" response more likely than a "no" response by increasing the number of trials where the test word actually appeared in the memory set shortens the Response Selection process for "yes" responses (stage 4, intercept) without influencing the slope.

On the other hand, when S is presented with a memory set followed by a test stimulus and is asked to name the item which appeared next to the test item within the memory set, the rate of scan (as indicated by a seven-fold increase in the slope, stage 2) is 1/7 as fast as usual, while the intercept is only slightly increased. Thus, when information about the order of items held in STM must be recalled and the response item must be named, the search slows dramatically. The slight increase in the intercept is presumably due to the additional time required for naming the response as opposed to responding "yes" or "no." Under

Figure 1.

Factors Affecting Four Stages of Processing in the Memory Search (Adapted from Posner, 1973; Sternberg, 1969a, 1969b)

Stage 1	Stage 2	Stage 3	Stage 4
Perception of the Test Stimulus	Search of Short Term Memory	Response Selection ("Yes" or "No")	Response Initiation
Factors Affecting This Stage Only:			
Clarity of Test Stimulus	Number of Items in Short Term Memory	Probability that a Test Item Was Actually in the Memory Set, i.e., Probability of "Yes" vs. "No" Responses	Compatibility or Ease of Execution of the Response



these conditions, the rate of memory search approaches the rate of implicit speech, which suggests that Ss are reciting the names of the items covertly during the search, rather than using the high-speed memory scan which is found in the Sternberg (1969a, 1969b) recognition paradigm.

In another study which is relevant to the question of the independence of slope and intercept measures, Chase and Calfee (1969) found that switching from an auditory stimulus presentation to a visual test mode increases the slope but not the intercept of the RT function. Apparently, additional time is required during the search process to translate each item in the memory set into the mode of the test stimulus. On the other hand, if the test stimulus were translated into the mode of the memory set, only the intercept would be increased, since this operation would happen only once during the scan. The assumption of the independence of processing stages reflected by the slope and intercept of the memory search function is supported by these experiments. The excellent fit of the linear model to the data (at least 95 per cent of the memory set size effect is linear) makes the assumption of the additivity of stage durations in the memory search process highly plausible (Chase and Calfee, 1969; Seamon, 1972; Swanson, Johnsen, & Briggs, 1972).

The Sternberg (1969) technique allows the measurement of the rate at which memory representations in STM are scanned as distinct from the time required and to select and execute the response which indicates the result of the STM search. Can the rate of scan be used as a basis for inferences about the form in which information is retained in memory? Clifton and Tash (1973) found that rate of scan did not differ for visually presented letters, one-syllable words, and three-syllable words. They interpreted their results as indicating that the memory representation was neither an articulatory, acoustic, nor a visual replica of the stimulus, since the physical characteristic of length (either auditory or visual) did not affect the slope, i.e., the rate at which stimuli held in memory could be compared with the probe. As would be expected, stimulus length affected the amount of time required to read or encode the test probe, as reflected by the intercept. Some more abstract type of representation would seem to be indicated here.

Other approaches yield results that are consistent with a less abstract memory representation, i.e., one which includes more of the attributes of the original stimulus. Chase and Calfee (1969) found that presenting consonants in one mode (visual or auditory) and testing in the other increased the slope in the Sternberg (1969a, 1969b) paradigm, even when Ss always knew the mode in which they would be tested. This finding suggests that the memory representations resulting from visual and auditory presentations of a letter are somehow different, and that time is required to convert each memory representation into some form which can be compared with the test stimulus. Similar translation processes may be required for some comparisons within modalities, as between an upper case letter held in STM and a visually presented lower case test letter (Posner, 1969). Further support for this proposition was found by Swanson, Johnsen, and Briggs (1972), who had Ss overlearn two-digit numbers as names for nonsense forms. Changing the mode (name vs. shape) between presentation and test caused a reduction in the rate of scan consistent with the expected process of translation from the mode of the memory representation to the mode of the test stimulus. This finding supports the hypothesis that two memory codes (name and shape) are involved in the context of this experiment rather than one common abstract one which is equally "close" to both types of stimuli in terms of comparison time.

The experiments cited above illustrate that the rate of memory search can provide clues as to whether some kind of visual, verbal, or abstract representation is involved. Memory search data may also be helpful in determining what type of representation results when S is asked to imagine a visual scene. There is a large body of evidence which indicates that instructions to generate pictorial interacting mental images from words or separate pictures in a paired-associate (PA) task dramatically improves recall and recognition performance (Paivio, 1971; Reese, 1970). Furthermore, Bower (1970) showed that instructions to generate an interacting image for each pair of words to be learned facilitated PA learning, while instructions to form separate images of the referents of the stimulus and response terms did not. Apparently it is the production of an interaction, not merely the generation of images per se, which is the effective process here. The problem, of course, is that it is not clear what covert processes are going on when instructions to generate interacting visual images are given.

Using the Sternberg paradigm, Seamon (1972) tested the proposition that instructions to use different encoding strategies could affect the way in which information was retrieved from STM. In that study, which involved stimulus sets of one to three words, independent groups of Ss were instructed (1) to repeat the words subvocally, (2) to generate separate images of their referents, or (3) to generate one image which involved the referents in interaction. In the repetition and separation imagery conditions, RT was found to increase linearly with the size of the stimulus set, with similar slopes for both "yes" and "no" responses. In the interaction imagery condition the size of the set did not affect the amount of time needed to indicate whether the probe stimulus was a member of the original set. In other words, when three stimuli in memory were combined to form an interacting image, they could be scanned as rapidly as a single stimulus.

Apparently the probe was compared with all the stimulus items one at a time in the first two conditions, while all stimuli could be compared with the probe simultaneously in the interaction imagery condition. Verbal repetition and separation imagery instructions resulted in sequential retrieval of information, while interaction imagery instructions led to the simultaneous availability or parallel processing of that information in STM. This result is consistent with the hypothesis that interaction imagery instructions caused a picture-like representation which was "all there at once."

Chapter III

STATEMENT OF THE PROBLEM

It is not clear that Seamon's (1972) results are due to the generation of interacting visual images rather than the generation of interactions of unspecified modality. Like imagery instructions, instructions to generate sentences using the terms to be learned in a PA task improve performance (Paivio, 1971). Paivio argues that both verbal and visual codes may be available to S in some situations. The question which arises is whether the effects of interaction instructions on memory search are found only in the case where visual "picture-like" imagery is presumed to be the means of interaction, or whether instructions to generate a sentence would result in simultaneous access to the terms involved in a sentence held in memory. In other words, does any type of mediational strategy (be it verbal or imaginal) yield simultaneous access to information stored in STM, or does the verbal strategy yield sequential access, as would be expected if a string of memory representations of words were scanned one after the other?

If a sentence generation instructional condition were found to involve serial comparisons (i.e., RT increases with the number of items to be scanned in memory), one could argue that interaction imagery and sentence generation instructions induce different kinds of retrieval (and perhaps storage) processes. In this case, the scanning of a generated sentence for a particular word could be characterized as a sequential, word-by-word (or phrase-by-phrase or piece-by-piece) process, while the scanning of a generated image could be likened to the viewing of a picture, where information is available more or less simultaneously.

On the other hand, if simultaneous comparison were found in a sentence generation condition (i.e., RT does not increase with the number of items to be compared), there is more than one interpretation of the data. One could argue, as do Begg and Paivio (1969), that concrete sentences are stored mainly as images, so that imagery would underlie the performance of both the sentence generation and interaction imagery groups. One could alternatively propose that information about interactions or relations -- whether produced by sentence or imagery instructions -- is stored and retrieved in an abstract propositional type of memory code which allows simultaneous access but which resembles neither words nor pictures (see Pylyshyn, 1973). The claim could also be made that sentence information is stored and retrieved in such a propositional fashion, but that imaginal information is treated in a quasi-visual way and each of these types is subject to a simultaneous search in memory.

Some investigators have argued that the slope values obtained in the Sternberg (1969a, 1969b) paradigms cannot be used to discriminate between serial and parallel search processes in STM (Atkinson, Holmgren, & Juola, 1969; Townsend, 1972). They propose parallel search models where comparison operations on all items in STM begin simultaneously (but may end at different times) which "mimic" serial processes and explain the usual linear increase in RT with memory set size (SS). In this sense, "parallel" does not mean that three items can be scanned in the same time as one, but merely that the scan begins on all items at once. The fact that the Sternberg (1969a, 1969b) technique cannot be used to indicate whether this type of parallel process is occurring as opposed to a serial one does not make it unsuitable for testing the central hypothesis in the present experiments. In the present case, it was predicted that interaction imagery processes would yield a simultaneous scan where there was no increase in RT as a function of SS. The serial search models and the parallel search models which "mimic" them, however, are designed to account for the usual increase in RT due to SS.

The argument can be made that the equivalence of "yes" and "no" slopes cannot be taken as evidence of a serial exhaustive search, since a serial self-terminating search with a random order and/or starting point would give the same result. Although this qualification limits the conclusions which can be drawn in general from the Sternberg (1969a, 1969b) paradigm, the inability of the model to discriminate between the two types of search is not crucial to the hypothesis that interaction imagery instructions yield a simultaneous search of STM.

Chapter IV

EXPERIMENT I

Method

Subjects -- Fifty university students (25 males, 25 females) served as Ss. All Ss had just served in a short experiment (15 minutes) concerning verbal and motor reaction times to the onset of a stimulus light.

Design -- Five groups of 10 Ss apiece were tested. Each group received one of four instructional strategies: (1) Subvocal Repetition, (2) Separation Imagery, (3) Interaction Imagery, and (4) Sentence Generation.[2] An additional Interaction Imagery group (5) was run with modified instructions after the first four conditions had been completed and the results had been analyzed. Data from this group were analyzed separately. Memory set size was varied within Ss in a mixed-list format. The Ss were randomly assigned to conditions in blocks of four, where each block constituted a replication of the experiment.

Procedure -- Sets of one, two, or three printed English concrete nouns were presented to Ss in horizontal arrays via slide projector cued by inaudible signals from a tape recorder. Stimuli in the memory set were presented simultaneously for a period determined by allowing five

[2] Conditions one, two, and three provide for a replication of the Seamon (1972) study, while condition four is an addition.

seconds for each item in the set. The stimulus set was followed three seconds later by an auditory warning signal (a "click" from the projector) and a probe word one second after the click. The probe word remained visible for seven seconds. Three blocks of 18 trials were presented. Each block contained six trials (three "yes" and three "no" trials) for each of the three memory set sizes. The order of presentation of blocks was counter-balanced across Ss, and the first block was considered practice. New words varying in lengths from three to nine letters were used on each of the trials, which were separated by inter-trial intervals of five seconds. For "yes" responses, each location on the screen (left, middle, right) of the probe word in the memory set was equally frequent.

Stimuli fell into three classes: (1) potential actors or subjects of an active declarative sentence, (2) likely receivers of action or direct objects, and (3) probable objects of a prepositional phrase which could specify how or where the action was carried out. The words in a set were selected so that they could be combined to form sentences (e.g., "cowboy, car, barn"; "scissors, hose, jug"; "cat, apple"; "knife, hammer"; "trench, glove, rake"). Each class of word was shown equally often in each location on the screen for set size three, while actors and objects appeared on the left and the right sides of the screen with equal frequency. Reaction times between the onset of the probe word and S's vocal "yes" and "no" responses were measured by an electric timer (accurate to o.ol second) synchronized with the projector which was stopped by a signal from a voice-operated relay.

In the Subvocal Repetition condition Ss were instructed to rehearse the memory set stimuli when they were presented and during the three-second retention interval which preceded the probe. The Ss in the Separation Imagery condition were told to generate a separate image of a referent of each stimulus word, and to keep the images spatially separate and non-interacting, while thinking about each in succession until the probe word was presented. In the Interaction Imagery condition, Ss were instructed to form an image for each of the stimuli, to combine these images into one interactive scene (in cases where there was more than one stimulus), and to concentrate on the imaginal scene until the probe word was presented. Instructions to Ss in the additional interaction imagery condition were modified to emphasize that the images in the scene should be touching one another. Examples of such images were shown, and the use of the interacting scene as the basis for judging the test word was stressed. In the Sentence Generation condition Ss were asked to form sentences which described an interaction among the stimuli. When three words appeared on the screen, Ss were told to incorporate them into a sentence which described one thing acting on another. The remaining word was to be used to tell how or where the action was accomplished (e.g.,"The cowboy drove the car into the barn."). For memory sets of two words, Ss were told to generate a sentence where one object was acting on the other (e.g., "The bus hit the tree."). When only a single word was presented in the stimulus set, Ss were told to rehearse it subvocally. The Ss were told to notify E if they were unable to comply with the imagery or sentence instructions on a particular trial rather than making a "yes" or "no" response. Examples were provided to Ss to make sure the task and instructions were understood. For full details concerning the materials and procedure used, see Appendices A and B.

Results

Trials where yes/no response errors were made were excluded from analysis. One such error occurred in each condition except the Separation Imagery group. Reported failures to generate images or sentences were likewise infrequent (only two in the Interaction Imagery condition) and were also excluded. Two Ss in the Separation Imagery condition who reported using interaction imagery were replaced.

The main hypothesis concerning the simultaneous or serial nature of the STM search process under different instructions was tested in two ways. First, following Seamon's (1972) procedure, linear trend comparisons based on the combined data from "yes" and "no" responses were conducted to evaluate the effects of memory set size on RT. Second, separate slopes were calculated for "yes" and "no" responses, and these values were tested to determine if they differed from zero. Additional comparisons were made within groups between slopes for "yes" and "no" responses in order to compare these results with the usual findings in the Sternberg (1969a, 1969b) paradigm. Comparisons were also made between groups for slope and intercepts to determine if instructions affected the encoding stage (intercept) and search stage (slope) of the task differently.

For the linear trend analysis, a median score for each set size and response type in each block was computed for each S. The median, rather than the mean, was used to reduce the effects of extreme scores (Chase & Calfee, 1969; Fischler & Juola, 1971). These medians were averaged across blocks and "yes" and "no" responses at each memory set size. In all conditions, linear trend comparisons revealed significant effects ($p < .05$, one tailed test) of set size (SS) on reaction time

(RT), while no quadratic trends were detected (see Table 1 for t-values). Rather than using a single common pooled variance in the error term for all conditions, the error variance associated with a trend contrast was computed for each condition. This was done since inspection suggested that the variances were not homogeneous across groups, (i.e., a seven-fold difference between the largest and the smallest values), and since SS effects within conditions were of interest.

A slope and intercept for RT as a function of SS were computed for each S using all "yes" and "no" responses for set sizes two and three. In order to make the present analysis comparable to that of Seamon (1972), "yes" and "no" responses for set size one were not considered. Although the reasons for this procedure were not made entirely clear, Seamon (1972) apparently intended to obtain estimates of the slopes for "yes" and "no" responses which were not affected by the longer latencies for "no" responses which are typically found at set size one. This effect is sometimes attributed to "response bias" (Chase & Calfee, 1969), although there are other explanations (Smith & Nielsen, 1970; Tversky, 1969).

These figures were then averaged within conditions to yield a mean intercept for each group for "yes" and for "no" responses (see Table 2 and Figures 2 and 3). Using the data from the four original conditions, an ANOVA was performed with conditions as the independent variable and with sex as a control variable. No hypotheses were made about sex effects, since the central proposition under test yields no predictions about sex differences, and since the small N (five males and five females per group) provided little power to detect sex differences within conditions. "Yes" and "no" slopes in all five conditions were tested

Table 1.

t-values for Linear and Quadratic Trends for the Effects of Memory Set Size on RT

Experiment I

Trend	Condition				
	Repetition	Separation Imagery	Original Interaction Imagery	Sentence	New Interaction Imagery
Linear	9.95*	11.72*	3.46*	6.87*	4.00*
Quadratic	-1.65	-.37	.29	1.91	.72

* $t(8) > 1.86$ yields $p < .05$, one-tailed test for predicted linear trend. $t(8) > 2.3$ yields $p < .05$, two-tailed test for quadratic trend.

Table 2.

Slopes and Intercepts for "Yes" and "No" Responses
Based on Set Sizes Two and Three
(in Hundredths of a Second)

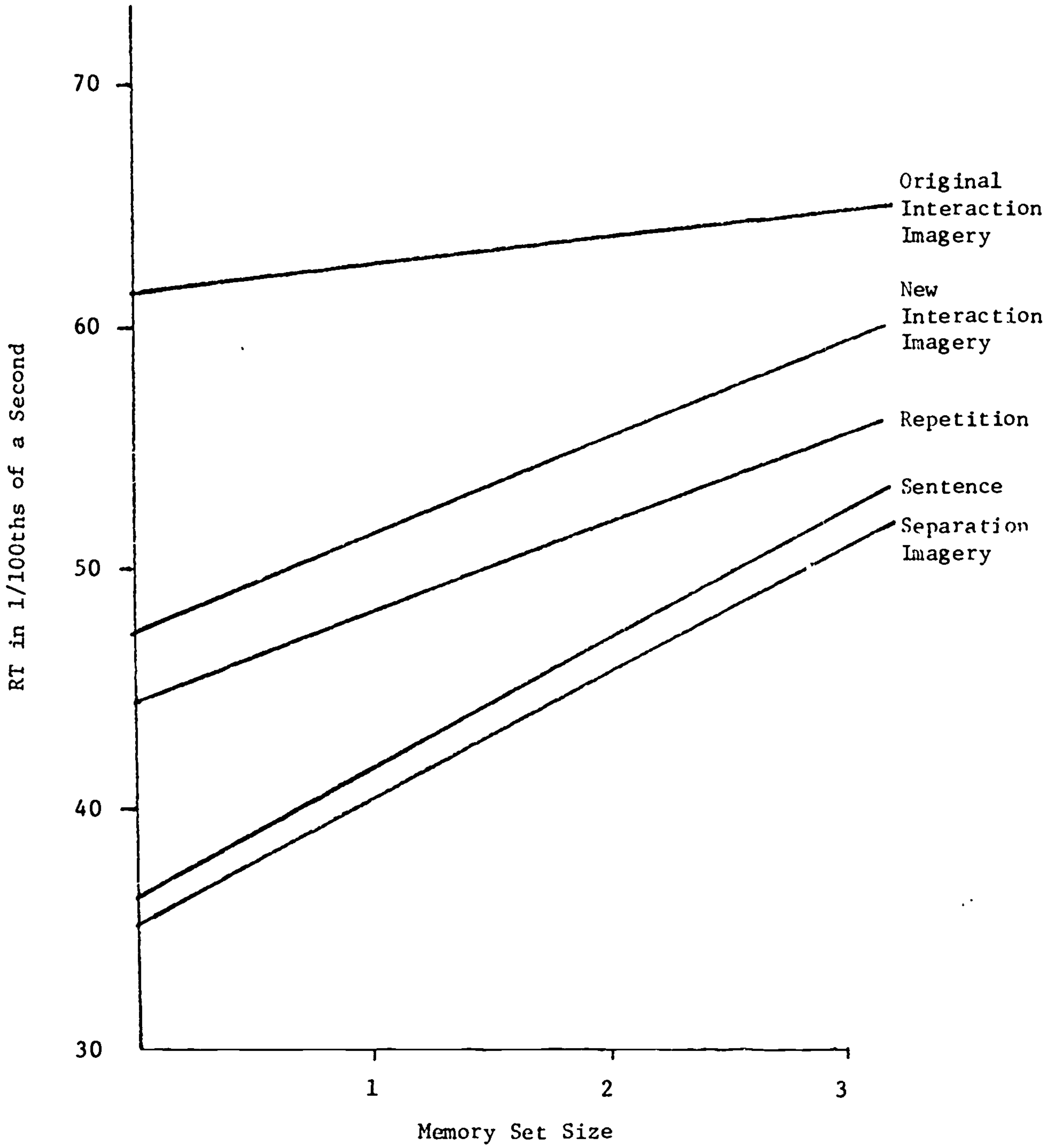
Experiment I

	Condition				
	Repetition	Separation Imagery	Original Interaction Imagery	Sentence	New Interaction Imagery
"Yes" Slope	4	6	1	6	4
"No" Slope	5	3	3	6	4
"Yes" Intercept	44	35	61	36	47
"No" Intercept	40	42	55	55	46

Figure 2.

The Relationship Between Memory Set Size and RT for "Yes" Responses

Experiment I

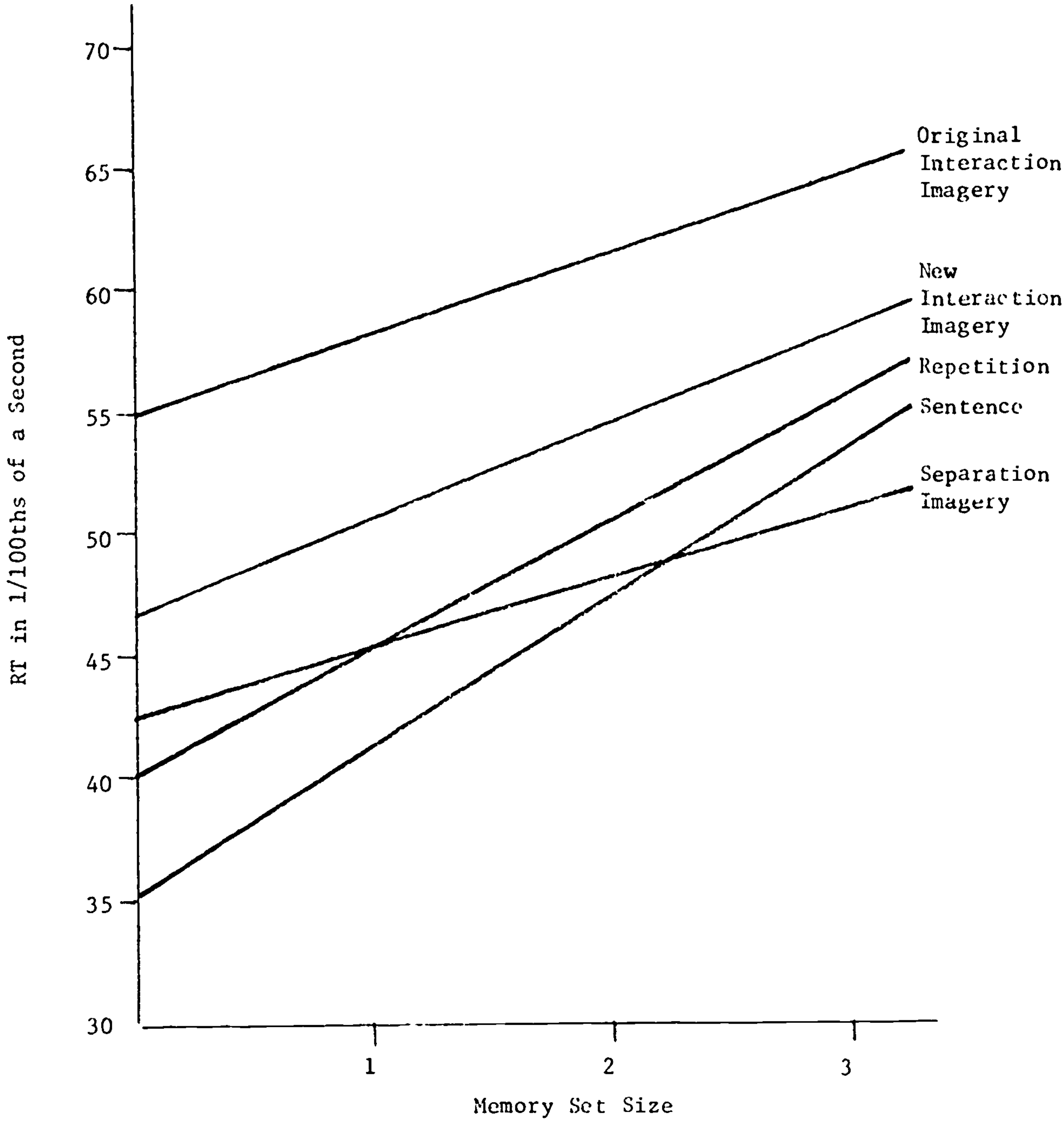


Note: This figure is based on average slope and intercept values derived from slope and intercept estimates computed for individual Ss.

Figure 3.

The Relationship Between Memory Set Size and RT for "No" Responses

Experiment I



Note: This figure is based on average slope and intercept es derived from slope and intercept estimates computed fo. individual S.

separately to determine if they differed from zero. All slopes showed such a difference except the "yes" slope in the original Interaction Imagery condition (see Table 3 for t-values). No significant differences for "no" slopes were found across conditions, $F(3,32) = 1.19$, $p > .05$. Slopes for "yes" responses differed significantly across conditions, $F(3,32) = 2.92$, $p < .05$, although no Tukey post hoc pairwise comparisons were significant at $\alpha = .05$.

Analysis of the intercept data for the four original groups showed differences across conditions for "yes" responses, $F(3,32) = 8.27$, $p < .05$, and for "no" responses, $F(3,32) = 2.95$, $p < .05$. Tukey pairwise post hoc comparisons at $\alpha = .05$ indicated that for "yes" responses, the intercept for the original Interaction Imagery group was larger than those of the Repetition, Separation Imagery, and Sentence conditions. For "no" responses, the original Interaction Imagery group displayed a greater intercept than the Sentence group.

Slopes and intercepts for "yes" responses were compared with those for "no" responses within all five conditions. One-sample t-tests revealed no "yes"/"no" slope differences in any condition ($p > .05$, two-tailed). A significant "yes"/"no" intercept difference was found only in the Separation Imagery condition where the intercept for "no" responses was greater than for "yes" responses ($p < .05$, one-tailed test; see Table 3a for t-values). A directional test was used in this case, since "no" intercepts were expected to exceed "yes" intercepts on empirical grounds, although the reason for this effect is unclear (Chase & Calfee, 1969; Smith & Nielsen, 1970; Tversky, 1969).

Immediately prior to serving in Experiment I all Ss had completed a reaction time task which involved making a simple vocal response ("go")

Table 3.

t-values for Determining if Slopes Differ from Zero

Experiment I

	Condition				
	Repetition	Separation Imagery	Original Interaction Imagery	Sentence	New Interaction Imagery
"Yes" Slope	3.79*	3.86*	1.22	4.00*	2.96*
"No" Slope	3.37*	2.23*	2.94*	5.00*	2.83*

* $t(8) > 1.86$ yields $p < .05$, one-tailed test.

Table 3A.

t-values for the Difference Between "Yes" and "No" Responses for Slopes and Intercepts

Experiment I

t-values	Condition				
	Repetition	Separation Imagery	Original Interaction Imagery	Sentence	New Interaction Imagery
Slope	-.54	1.27	-1.35	.20	-.05
Intercept	-1.62	-1.84*	-.90	-.96	-.45

* $t(9) > 1.83$ yields $p < .05$, one-tailed test for intercepts.

$t(9) > 2.3$ yields $p < .05$, two-tailed test for slopes.

as rapidly as possible to the onset of a light. It was hoped that this "vocal speed" measure could be used as a covariate. However, the correlation between Ss' total reaction time on all trials and vocal speed was significant only in the Sentence condition ($r = 0.67$, $p < .05$, one-tailed test), so this plan was dropped (see Table 4). The correlation between vocal speed and the Y-intercept for the memory scan task was significant only for "yes" responses in the Sentence condition ($r = 0.70$, $p < .05$, one-tailed test). Since the latency of the vocal response is one of the components of the Y-intercept, this correlation would be expected to be larger than that between vocal speed and total reaction time, and thus more effective in removing the effects of individual differences in vocal speed within the analysis of covariance. Such was not the case (see Table 5). See Appendices C and D for RT and slope and intercept data for individual Ss.

Discussion

Contrary to Seamon's (1972) results, interaction imagery instructions did not cause a simultaneous search of STM in the present experiment. In all conditions, significant linear trends were found for RT as a function of memory set size. Additional items in memory required extra time to be scanned, regardless of instructions given to Ss.

There were no differences in slope due to conditions, and there were no cases where "no" slopes exceeded "yes" slopes. These findings support Sternberg's (1969a, 1969b) view of the memory scan as an exhaustive serial process with a rate of 38-50 m.sec. per item. The one instance of a slope of zero occurred for "yes" responses in the original Interaction Imagery condition, but was not replicated with

Table 4.

Correlation of Vocal Speed with the Total Time Required in All Trials of the Memory Scan Task

Experiment I

	Condition				
	Repetition	Separation Imagery	Original Interaction Imagery	Sentence	New Interaction Imagery
r	.37	.54	.03	.67*	.02

Table 5.

Correlation of Vocal Speed with the Y-Intercepts for "Yes" and "No" Responses in the Memory Scan Task

Experiment I

	Condition				
	Repetition	Separation Imagery	Original Interaction Imagery	Sentence	New Interaction Imagery
r for "Yes" Responses	-.04	.33	.14	.70*	.21
r for "No" Responses	.36	.40	.14	.21	.16

* Pearson $r > .55$ yields $p < .05$, one-tailed test.

either response type in the new Interaction Imagery group. Since an interaction imagery process would be expected to yield a simultaneous scan (zero slope) for both "yes" and "no" responses, the one instance of a zero slope cannot be taken as support for Seamon's (1972) hypothesis.

These data indicate that the nature of the memory search (simultaneous versus serial) is not affected by imagery or sentence generation instructions. The original Interaction Imagery group did display significantly higher intercepts than other conditions, which could indicate that interaction imagery instructions cause additional processes which precede the memory scan. These high intercepts must be interpreted with caution, since they were not replicated (descriptively speaking) in the new Interaction Imagery group, which performed more like the Control group than like the original Interaction Imagery condition.

Seamon (1972) predicted that a relational imagery strategy would cause a simultaneous, rather than sequential search of items in STM. He tested his hypothesis with six S̲s per group in a three-group design. He found no effect of SS on RT in the relational imagery group. This finding was taken as confirmation of the prediction, even though a similar result was found for the Separation Imagery condition, which should have yielded an effect of SS on RT such as that found in the repetition group. Seamon also employed a trend analysis. Significant linear trends were found for the Repetition and Separation Imagery conditions, but not for the Relational Imagery group. This finding, which is contrary to the results of the analysis of SS effects on RT, was interpreted as support for the hypothesis that a relational imagery strategy would cause a simultaneous search of STM.

Confirming a hypothesis by failing to reject the null hypothesis is a tricky thing; one is always subject to the criticism that the null hypothesis would have been rejected if greater statistical power had been brought to bear by using more Ss or more sensitive measures. The fact that in the present experiment significant linear effects of SS on RT were found in two Interaction Imagery groups of 10 Ss apiece suggests that Seamon's findings were due to a lack of power. A similar failure to replicate Seamon's (1972) results adds weight to this explanation.[3]

A closer examination of the task indicates that even if a relational imagery strategy caused a simultaneous scan of items in STM, this effect might be concealed due to the fact that Ss presumably had to make some type of translation or modality switch between generated visual images held in memory and the printed words used as test stimuli. Chase and Calfee (1969) and Swanson, Johnsen, and Briggs (1972) found that such translations (switching from an auditory presentation of a word to a visual test stimulus and the reverse in the first case; switching from a nonsense shape to an associated nonsense label and the reverse in the second) increased the slope of the RT function in the Sternberg (1969a, 1969b) task. This finding is congruent with the porposition that each comparison of a memory representation with a test stimulus includes the additional time needed to translate the memory representation into the mode of the test stimulus for comparison. If, on the other hand, the test stimulus were translated into the mode of the memory representation (an

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[3] Allan Paivio (personal communication, Annual Meeting of the American Educational Research Association, Chicago, Ill., April, 1974) indicated that he had failed to replicate Seamon's (1972) findings.

operation that would happen once in the memory scan regardless of memory set size) an increase in intercept, rather than slope, would be expected, since a constant translation time would have been added to RT regardless of SS. The point here is that the slope increases found by Chase and Calfee (1969) and Swanson et al. (1972) would tend to counteract any slope reduction or tendency toward simultaneous scan in Seamon's (1972) task. For this reason, a recognition task which involves a comparison between a presumed image held in STM and a word as a test stimulus does not provide a suitable test of the hypothesis that interactive imagery allows a simultaneous search of all the objects in the image.

Generalizing from the Chase and Calfee (1969) and Swanson et al. (1972) data one would expect a greater slope in the Separation Imagery condition than in the Control condition in the present experiment. This difference should occur since Ss in the imagery group would have had to translate between images in memory and presented test words, while Ss in the control condition would not have had to make this translation. Such a slope difference was not found. This finding suggests at least two possibilities: (1) Ss did not generate images and (2) Ss generated images, but these were not used as the basis of the memory search. The fact that words were used as test stimuli may have discouraged Ss from either generating images or using them as a basis of comparison with the test stimulus, since the imagery and translation processes may have been seen by Ss as conflicting with the basic instructions to "Respond as quickly and accurately as possible."

Chapter V

EXPERIMENT II

Introduction

In order to test the hypothesis that interaction imagery causes a simultaneous scan it was necessary to eliminate the presumed image-word translation process and to encourage Ss to make use of a visual code. A second experiment was designed in which all materials were pictorial and where the effects on memory scan of depicted visual interactions between pictured objects (in the Provided Interaction condition) could be compared with those of interactions generated covertly by Ss from spatially separate pictures of the objects (in the S-generated Interaction condition). For example, a provided interaction might consist of a picture of a cat eating an apple or a knife cutting a hammer, where the two objects were in contact and one was acting on the other. In the S-generated Interaction condition, Ss would be asked to visualize such an interacting scene when they were presented with pictures where a cat and an apple or a knife and a hammer were shown as separate objects which were not interacting.

To determine if Ss were complying in some way with the instructions to generate visual interactions, an unexpected paired-associate (PA) task was administered on set size two items at the end of the experiment. Since it is known that such instructions improve even incidental associative learning (Rowe & Paivio, 1971), superior PA performance could be taken as evidence that Ss were attempting to comply with instructions and were actually engaging in some strategy. It is the effects of this interaction strategy on the rate of memory scan which are of interest here.

Processes which precede the memory scan are also under investigation in the present design. The finding that in Experiment I the Interaction Imagery group displayed significantly higher intercepts in the RT/SS function than other groups (a result which was not replicated, descriptively speaking, in the new Interaction Imagery condition, however) suggests that subjects in the Interaction Imagery conditions may have had to do something additional before beginning (or, less likely, after completing) the memory scan. It may be that an interactive image must be "taken apart" into its component pictures before it is scanned for a match to a test stimulus. Comparison between Interactive Imagery groups (both Provided and S-generated) and an uninstructed group which views separated pictures should also reveal relatively high intercepts in the Imagery groups if this hypothesis is correct.

Method

Subjects -- Thirty graduate students (15 males, 15 females) served as Ss.

Design -- Three groups of ten Ss apiece were compared: Control, Provided Interaction, and S-generated Interaction. Memory set size (SS 1 and 2) was varied within Ss in a mixed-list format.

Procedure -- Sets of one or two line drawings of common objects (e.g., a house, a cat, a truck, a ball) were presented by a slide projector cued by inaudible signals from a tape recorder. Stimuli for set size one and all test items were centered on 2 x 2 slides. Set size two stimuli in the Control and S-generated interaction conditions were positioned symmetrically about the mid-point of the slide, and the depicted interactions between objects for set size two in the Provided Interaction condition were centered in the slide frame. In cases where the test stimulus matched a presented item in the memory set, both were in the same orientation. This was done since RT measures have been found to be sensitive to orientation changes between pictures presented at the acquisition and test phases of a recognition task (Frost, 1972).

Presentation times for stimuli and test items were identical to those used in Experiment I for Set Sizes one and two, where five seconds was allowed for the presentation of each item in the memory set. As in Experiment I, the memory set was followed by a three-second blank interval and an auditory warning signal, a test stimulus of seven seconds duration one second after the signal, and, finally, by an inter-trial interval of five seconds. "Yes" and "no" responses were equally likely, and each of the two serial positions for the target picture for "yes" responses in set size two was equally frequent. Latencies of Ss' vocal responses were measured with the equipment used in Experiment I. A preliminary block of nine trials was considered practice. Two blocks of 20 trials each (counterbalanced for order across Ss) yielded ten "yes" and ten "no" items at each memory set size.

In the Control and Provided Interaction conditions, Ss were told to fixate visually on a dot centered on the screen while attempting to maintain a visual image of the stimulus picture(s) during the three-second retention interval. Those Ss in the generated interaction condition were asked to imagine a visual interaction between the two stimuli presented side by side for set size two and to center this interaction on the dot. Examples of pictorial interactions where two objects were touching and physically interacting in some way were shown. The Ss were told to indicate at the time if they failed to construct an interaction on a particular trial. All Ss received four "example trials" to clarify the nature of the task. An unexpected self-paced PA recall task where the names of the left-hand members of set size two items were used as a stimuli was given at the conclusion of the experiment. For full details concerning the materials and procedures used, see Appendices E-G.

Results

As in Experiment I a median score for each set size and response type in each block was computed for each S; these were then averaged across blocks to provide the data for an ANOVA. The Ss' raw scores on each trial were used to generate a slope and an intercept value for each individual.

On several trials in the entire experiment Ss were apparently inattentive and yielded an occasional extremely long response latency. To avoid misleading slope and intercept estimates, outlying scores which would have doubled the range within a block of tials if they had been included were discarded. Relatively few scores had to be deleted in this manner: three for the Control condition, eight for the Provided Interaction condition, and four for the S-generated Interaction condition out of a grand total of 1,200 responses. One S who indicated that he did not understand the instructions after completing the first block of trials was replaced. No "yes"/"no" response errors were made, and only one case of failure to generate an interaction was reported

Significant effects ($p < .05$, one-tailed test) of SS on RT were observed in all groups (for the Control group t (9) = 4.32, for the Provided Interaction group t (9) = 2.94, and for the S-generated Interaction group t (9) = 8.78). All slopes were found to differ from zero ($p < .05$) except the slope for "no" responses in the Provided Interaction condition (see Table 6 for t-values). Slopes and intercepts for the three experimental conditions are shown in Table 7 and graphically represented in Figures 4 and 5.

An ANOVA based on the average slope for each response type in each condition showed no differences for either "yes" or "no" slopes across groups, $F(2,24) = 0.09$, $p > .05$ for "yes" slopes; $F(2,24) = 1.8$, $p > .05$ for "no" slopes. Intercepts for "yes" responses did not differ across conditions, $F(2,24) = .83$, $p > .05$, while intercepts for "no" responses did, $F(2,24) = 7.47$, $p < .05$. Tukey pairwise post hoc comparisons at $\alpha = .05$ indicated that the Provided Interaction group displayed a significantly larger "no" intercept than either the Control or the S-generated Interaction groups. This difference may have been caused by two Ss in the Provided Interaction group who were particularly slow in responding. When the extremely high intercepts of these Ss are removed from the analysis the mean for this group becomes 49, and it no longer differs from the Control ($p > .05$), but differs from the S-generated Interaction group exactly by the critical value of 10 required for significance at $p < .05$.

Slopes and intercepts for "yes" responses were compared with those for "no" responses within conditions. One-sample t-tests showed "yes" slopes to be significantly greater than "no" slopes with a two-tailed test in the Provided Interaction condition, t (9) = 2.5, $p < .05$ with a

Table 6.

t-values for Determining if Slopes Differ from Zero

Experiment II

t-value	Condition		
	Control	Provided Interaction	S-generated Interaction
"Yes" Slopes	4.28*	2.29*	4.04*
"No" Slopes	3.06*	1.24	10.4*

* $t(8) > 1.86$ yields $p < .05$, one-tailed test.

Table 7.

Slopes and Intercepts for "Yes" and "No" Responses (in Hundredths of a Second)

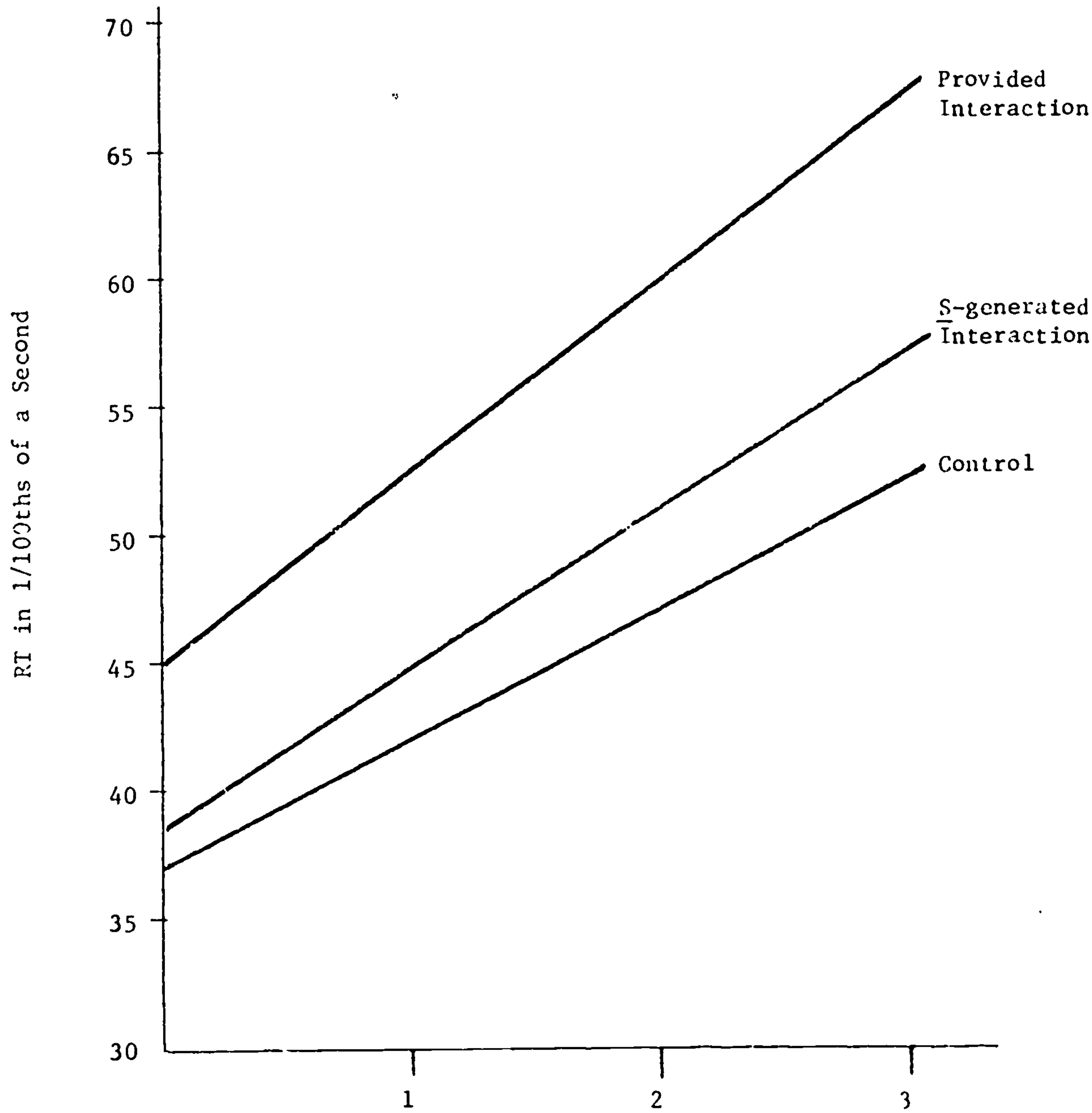
Experiment II

	Condition		
	Control	Provided Interaction	S-generated Interaction
"Yes" Slope	5	7	6
"No" Slope	3	2	5
"Yes" Intercept	37	45	38
"No" Intercept	41	54	39

Figure 4.

The Relationship Between Memory Set Size and RT for "Yes" Responses

Experiment II

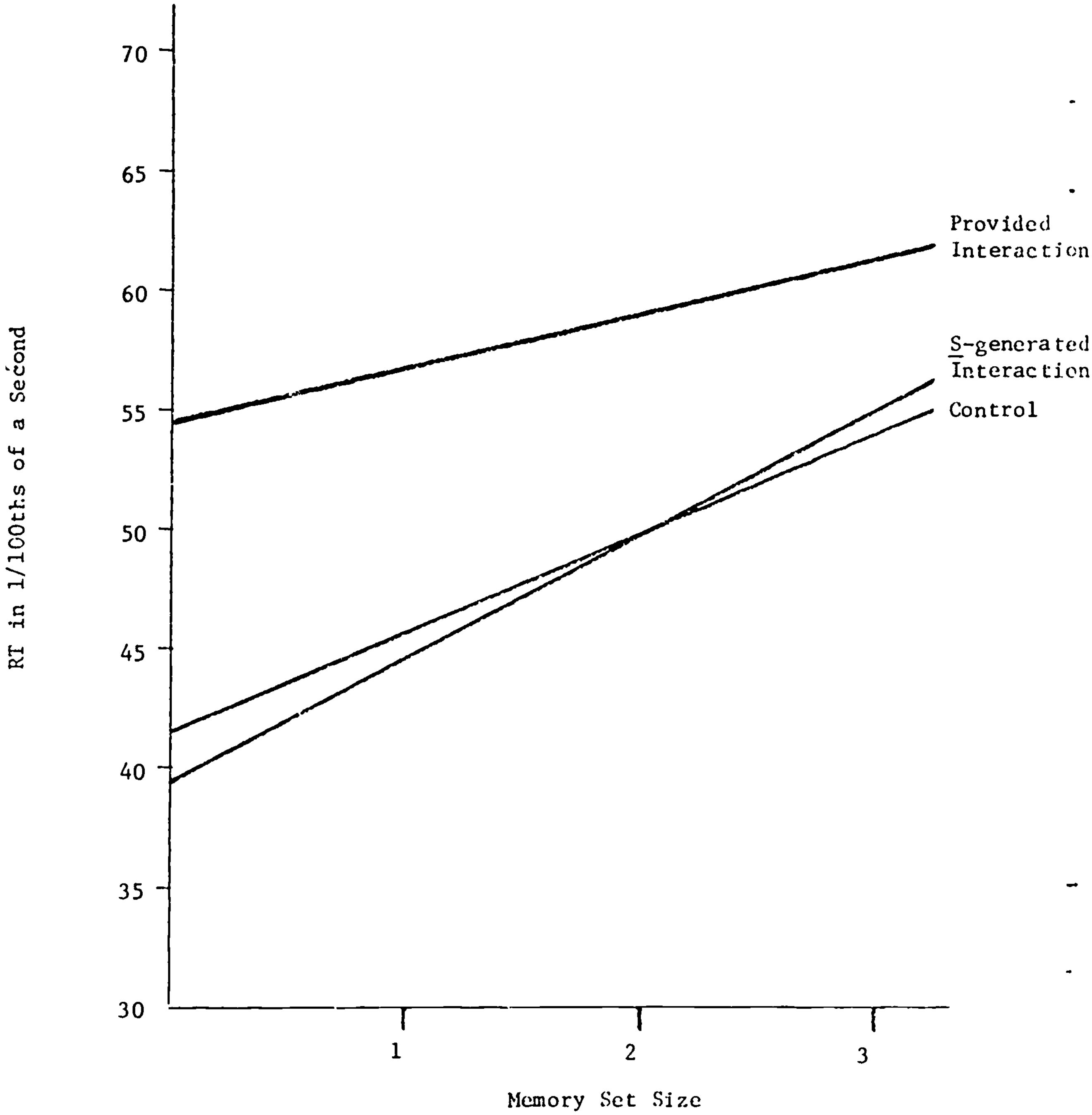


Note: This figure is based on average slope and intercept values derived from slope and intercept estimates computed for individual Ss.

Figure 5.

The Relationship Between Memory Set Size and RT for "No" Responses

Experiment II



Note: This figure is based on average slope and intercept values derived from slope and intercept estimates computed for individual Ss.

two-tailed test. In the same group, "no" intercepts were greater than "yes" intercepts, t (9) = 3.57, $p < .05$ with a two-tailed test. When the data from two Ss with outlying scores (e.g., "yes" slopes of three times larger than the mean, or 1.5 standard deviations from the mean, yielding "yes"/"no" differences of two and three times the mean "yes"/"no" slope difference) are excluded, "yes"/"no" differences are not significant for slopes, t (7) = 1.79, $p > .05$, two-tailed, but remain significant for the intercept, t (7) = 3.34, $p < .05$ two-tailed. No differences were found in the Control condition between "yes" and "no" intercepts, t (9) = 1.24, $p > .0$[illegible], or between "yes" and "no" intercepts, t (9) = -1.49, $p > .05$. The S-generated Intercation condition also failed to display "yes"/"no" differences for slopes, t (9) = 0.15, $p > .05$ and intercepts, t (9) = 1.25, $p > .05$.

In the incidental test of PA learning of SS2 stimulus pairs both the Provided and S-generated Interaction groups were superior to the Control group (see Table 8 for PA scores; $p < .05$, for Tukey post hoc comparisons, $F(2,24) = 16.7$, $p < .05$ for overall test). The variance of the Provided Interaction group (20.8) is surprisingly higher in the PA task relative to that of the S-generated Interaction (10.2) and Control (7.1) groups. A similar situation is found when variances in the memory scan task are summed over response type and SS, where the figures for the three groups are 1,134; 401; and 388; respectively.

In another PA study, however, (Kerst & Levin, 1973) variability was found to be larger when fourth and fifth grade Ss generated their own visual or verbal mediators rather than using provided ones. This finding suggested that individual differences in this age group are larger for mediator generation than for the usage of provided mediators.

Table 8.

Number of Correct Responses in the Incidental Paired-Associate Recall Task

Experiment II

	Condition		
	Control	Provided Interaction	S-generated Interaction
Number Correct	4.5	12.5	12.5

The apparent reversal of this effect in the present study is probably due to the fact that Ss in the Provided Imagery group are simply more heterogeneous in general than those in the other conditions. This proposition is supported by the finding that RT's for both SS1 and SS2 were consistently more variable in this group than in others. Differences in variance at SS1, where stimuli were identical across conditions, make this explanation particularly compelling.

An additional finding concerning the relationship between the PA and STM search tasks was that total RT correlated with PA performance -0.09 in the Control condition, -0.63 in the Provided Interaction condition, and -.54 in the S-generated Interaction condition. This correlation is significant only in the Provided Interaction condition ($p <$ .05, two-tailed test). These results indicate that Ss in the Provided Interaction condition who responded rapidly in the memory search task performed well on the PA task. See Appendix H for RT and slope and intercept data for individual Ss.

Discussion

The vastly superior PA performance of the S-generated Interaction group relative to the Control condition indicates that Ss in the former group complied with the interaction instructions in some way throughout the experimental session, since such instructions normally improve learning in a standard PA task. The facilitative effects of provided visual interactions obtained in the present experiment are also congruent with findings in the conventional PA paradigm.

Contrary to Seamon's (1972) hypothesis, the rate of memory scan, as reflected by the slope of set size/reaction-time function, is not affected by either an S-generated or depicted visual interaction between items in the memory set. Memory scan rates were comparable to the 38-56 m.sec. per item figures obtained by Sternberg (1969) with digits and pictures. Although the Provided Interaction condition displayed a horizontal slope of 0 for "no" responses which would be expected in a simultaneous scan, this result was unsystematic in that it was not found for "yes" responses in the same condition or for either response type in the S-generated Interaction group.

For all conditions, RT's for SS2 were greater than those for SS1, indicating a sequential rather than simultaneous search through items held in STM. This method of analysis, where group means for "yes" and "no" responses are combined at each set size, is identical to Seamon's (1972) procedure. The zero slope obtained in the previous method is probably due to a reduction in power caused by analyzing "yes" and "no" responses separately.

It is important to emphasize that the memory representation(s) of two interacting pictures is (are) searched at the same rate as that of two separate pictures. Prior knowledge of this finding would have led one to doubt that S-generated visual interactions would be subject to a simultaneous scanning process in memory. Providing pictorial interactions between objects or asking Ss to produce them from separate pictures dramatically improves associative learning of the members of each pair. The memory representation(s) of two interacting pictures or of two separate pictures coupled by a "mental image interaction" is (are) searched in STM at the same rate of the representations of two separate pictures, however. Neither type of interaction yields temporal (or spatial) unity.

It had been proposed earlier that the large intercepts obtained in the original Interaction Imagery group in Experiment I might be due to additional time required to "pull apart" an interactive image before objects in it could be searched for a match to the test stimulus. The results of Experiment II do not support this hypothesis, since intercepts in the S-generated Interaction condition do not differ from those in the Control group. Intercepts in the Provided Interaction group are no larger than those in the Control condition, which indicates that depicted interacting pictures require no additional pre-scan processing time compared to separate pictures. The only intercept difference obtained was for "no" responses between the S-generated and Provided Interaction conditions. This isolated difference was not predicted and is difficult to explain if one maintains the position that S-generated and provided pictorial interactions should somehow behave alike, while separate pictures should be processed differently than both types of interactions.

Although provided and S-generated interactions somehow "unite" the stimulus and response terms in the PA paradigm, rate of STM scan is a measure which is not sensitive to factors related to this effect, since separate pictures are scanned at the same rate as interacting ones. The possibility that this result is due to certain features of the present paradigm is discussed in the following section.

Chapter VI

GENERAL DISCUSSION

The results of Experiments I and II indicate that increasing the number of items held in STM increases the amount of time required to search through them when Ss generate covert visual interactions from presented words or picture items, and even when such interactions are explicitly provided in a drawing of interacting pictures. The more items that are held in STM, the longer it takes to search through them, even when Ss engage in strategies which "unite" these items in LTM in terms of PA recall.

The failure to replicate Seamon's (1972) finding that S-generated imagery allowed a simultaneous scan of the contents of STM has been considered earlier in the Discussion section of Experiment I. The argument was made that the original finding was due to a lack of power to detect SS effects on RT. Two additional points should be mentioned here. First, support for the simultaneous-scan conclusion consists of not finding a linear increase in search time due to additional items in the memory set. Since linear effects were consistently found in the present experiments, the argument cannot be made that the failure to replicate Seamon's (1972) results was due to the fact that the equipment he used allowed more precise measurement of RT (.001 sec. rather than .01 sec.) than the apparatus used here. The greater measurement error in the present experiment would be expected to bias the results in the direction of Seamon's findings -- i.e., the failure to detect an effect of set size on search time. This did not happen. Second, in Experiment II conditions were optimized for the use of a visual image interaction as the basis of memory search by either providing interaction instructions and separate pictures or by supplying depicted interactions while using a pictorial test stimulus in both cases. Even under these conditions where no translation between verbal and visual information at the time of test was required, no support for the hypothesis of a simultaneous scan of interacting items in memory was found.

Real interacting pictures, like pictorial interactions which are generated "in the head," are retained in some form which is not scanned all at once in memory. Seamon's (1972) formulation of the imagery/simultaneous scan hypothesis is intuitively appealing, and his adaptation of the Sternberg (1969a, 1969b) paradigm to test it is elegant. When one considers the data from the present studies which do not support this proposition, one can view the results of other experiments with the 20/20 vision of hindsight which renders the original imagery hypothesis less plausible. For example, Neisser and Kerr (1973) found that imagery instructions which required Ss to generate "concealed images" from provided sentence frames (e.g., "__________ is inside the breast pocket of Napoleon's coat") were as effective as ordinary imagery instructions (e.g., "__________ is sitting on top of the torch held up by the Statue of Liberty") in boosting sentence recall as compared with instructions and sentence frames which stressed separation imagery (e.g., "Looking from one window, you can see the Statue of Liberty; from a window in another wall you see __________"). The "concealed image" is effective as a mnemonic, yet is not so picture-like that it would tempt one to predict that it could be scanned simultaneously because all its parts were "visible" at once, since they were in some sense "invisible."

Posner, Boies, Eichelman, and Taylor (1969) report other evidence which suggests that generated visual representations lack other properties which pictures have. The RT data have been gathered in experiments where Ss are asked to indicate if printed letters (separated by a short retention interval) are the same, and where the letters either have the same name (e.g., A;a) or are physically identical (e.g., A;A). The finding that physical matches are more rapid than name matches is taken as evidence that the mental representation includes some visual aspects of the letter. In some experiments, an orally presented letter is followed by a visual test stimulus. When Ss are given time in which to generate a visual representation of the orally presented letter, RT in the auditory/visual case approaches that in the visual/visual case. This effect, along with other evidence, suggests that some visual components of the letter are covertly produced and used as the basis for the matching task. A mentally imagined "A", however, seems to be neither upper nor lower case, since the case of the visually presented test stimulus does not affect RT when Ss are told to visualize upper case letters from the auditorily presented stimuli. Posner et al. (1969) raise the possibility that this generic yet somewhat visual representation of a letter may be characterized as a set of features. At any rate, generated visual representations of letters hardly seem picture-like. The imagery/simultaneous-scan hypothesis, based on the metaphor of visual imagery as a picture-like process, loses its simple appeal in this context (see Pylyshyn, 1973, for an excellent critique of mental imagery and the pictorial analogy).

The present experiments do not support the proposition that STM search rates reflect processes such as interaction imagery and sentence generation, which can be used to tie together or integrate separate words or pictures in long-term memory for paired associates (Reese, 1970). There is evidence, however, that STM search rates reflect a certain type of unity or integration among elements in LTM. Clifton and Tash (1973) found the rate of memory search did not differ for letters, one-syllable words and three-syllable words. For example, the memory set "umbrella, factory, apricot" would take no longer to scan than the set "duck, pot, rag," even when steps were taken to insure that Ss were rehearsing whole words and not merely the initial letters. This suggests that the memory representation of a word is not a string of sequentially scanned discrete elements such as letters or phonemes, but some sort of integrated entity which is scanned at a rate which is independent of the number of units it contains. In contrast, Swanson, Johnsen, and Briggs (1972) found that the memory scan rate for one-, two-, and three-digit numerals was inversely proportional to the number of digits in each numeral to be scanned. Apparently, the memory representations of numerals do consist of discrete non-integrated elements where quantity affects the rate of the memory scan. This is intuitively reasonable, since each digit represents meaningful information independent of the others, while all letters in a word must be combined before meaning can be derived from them.

In an attempt to find if there are larger "chunks" of information which are scanned at once as integrated units, one could use compound words and adjectives or prepositional phrases as stimuli in the present paradigm, where scan rates should be independent of stimulus length if the elements within a stimulus are integrated in a form which can be scanned all at once in memory. Note that in this case it is the "size of the stimuli in the memory set which is varied in order to determine how "large" a memory representation can be and still be scanned as one unit. In the present experiments, however, manipulations were designed to encourage Ss to combine the stimuli in the memory set either visually (in the various interaction imagery conditions) or verbally (in the Sentence condition) in order to test the proposition that all items in the memory set would be scanned as if they had been combined into one unit. These manipulations did not lead to a simultaneous scan of combined items. Clifton and Tash's (1973) results indicate, however, that representations of elements within an item (e.g., the letters, or syllables which comprise a word item) are subject to a simultaneous scan.

What explains the difference between these two sets of findings? It may be that it is the kind or size of the test stimulus which governs what elements will behave as units in memory. That is, when a word or a single picture is used as a test stimulus, individual words or pictures, rather than interacting scenes, are treated as distinct units in STM. This coding process would seem to be appropriate when S is required to compare memory representations with external stimuli on the single word or picture level. In this way, the memory representation and the external stimulus to which it is compared are chunks of equal size which share the same types of information.

Similarly, when Clifton and Tash (1973) used words of varying length as memory set items and test stimuli, the word, rather than the letter, appeared to be the basis of the memory representation, since word length did not affect the rate of scan. If words were used in the memory set, while S was given a letter as a test stimulus, the single letter would be expected to become the memory unit, and the number of letters in a word would be expected to affect the search rate. The over-learned unity of words in memory should dissolve with this change in the demands of the task. The result of this process would be that the memory representation and the test stimulus would become congruent again, as they were when whole words were used as test probes and memory set items.

If it is found that Ss operate in the memory search task to keep each stimulus in the memory set similar to the test probe in terms of chunk size (when the test probe is of smaller size than the memory set item), one would want to determine if this principle holds when the test probe is larger than the presented memory set stimuli. In other words, will S combine items in the memory set and scan them as one unit in order to make the representation in memory comparable to the test probe in terms of the kind or amount of information contained? This question is a restatement of the interaction strategy/simultaneous scan hypothesis, where the requirements of the task have been changed so that an interaction strategy should be conducive instead of antagonistic to efficient performance in the STM search.

For example, test stimuli could consist of compound pictures such as a cat eating an apple or a scissors cutting a hose from a jug. Memory set stimuli would be separate pictures of a cat, an apple, etc. The S-generated interaction imagery applied to the memory set stimuli would serve to make the memory unit comparable in complexity to the test probe. If no differences in RT were found between memory set sizes two and three under these conditions, a simultaneous comparison process would be indicated. A condition where compound pictures were used as both memory set stimuli and test probes would be included to determine if the mental representation of interacting pictures which are actually presented are scanned in memory "at a glance."

This approach to the interaction imagery/simultaneous scan hypothesis shows it to be just one facet of the more general issue of how visual information is retained in memory. Template theories have been proposed for visual memory, where a template would be simultaneously scanned as one memorial unit. Feature theories, where features are scanned either serially or in parallel, are the key rival viewpoints to the template model. Here, "in parallel" means that the search begins on all features at once, but may vary in duration with the number of features involved. Template models, however, do not predict an increase in search duration due to an increase in the quantity of features scanned (Smith & Nielsen, 1970).

These investigators and others (Egeth, 1966; Nickerson, 1967) have studied how a current visual stimulus is compared with the memory representation of a previous one in a "same-different" judgment task. For example, the effects on RT due to varying the number of features or dimensions of a visual stimulus which are potentially relevant to S's judgment have been studied. RT effects due to the number of features on which the memory and test stimuli actually differ have also been explored in order to test template and feature models (see Neisser, 1967, for a general treatment of the feature/template controversy).

The research strategy which is proposed here is to compare the known properties of memory representations of compound visual stimuli with the properties of representations which result when Ss are asked to combine separately presented visual elements to form a compound product. This involves basically a contrast between S-generated and provided interaction imagery processes, where the memory and test stimuli are of comparable chunk size, and where something is known about the representations of provided compound visual materials. The extent to which provided and S-generated visual representations behave alike under these conditions should indicate whether or not S-generated interaction imagery involves some quasi-visual process.

APPENDIX A

Lists of Memory Set Words and Test Words

Experiment I

List 1

	Set Size	Memory Set Words	Test Word	Correct Response Same/Different
1	1	Banner	Sailor	D
2	3	Doughnut Wagon Ant	Wagon	S
3	2	Belt Wheel	Pillow	D
4	1	Table	Table	S
5	2	Boat Frog	Boat	S
6	3	Bear Clock Lake	Baby	D
7	2	Dollar Ring	Kite	D
8	1	Whistle	Whistle	S
9	3	Chimney Crab Egg	Bowl	D
10	2	Hand Bottle	Bottle	S
11	3	Whale Cigar River	Whale	S
12	1	Pumpkin	Needle	D
13	3	Shovel Stone Jar	Jar	S
14	1	Knapsack	Funnel	D
15	2	Lamp Key	Lamp	S
16	3	Scissors Hose Jug	Bolt	D
17	2	Tree Bus	Elbow	D
18	1	Kettle	Kettle	S

List 2

	Set Size	Memory Set Words	Test Word	Correct Response Same/Different
1	1	Saddle	Balloon	D
2	2	Soldier Fish	Box	D
3	3	Cannon Acorn Pail	Acorn	S
4	2	Hat Chair	Chair	S
5	1	Guitar	Ladder	D
6	3	Car Barn Cowboy	Web	D
7	1	Bandit	Bandit	S
8	3	Castle Arrow Window	Window	S
9	2	Pig Sun	Blanket	D
10	3	Lock Fence Saw	Rainbow	D
11	1	Cactus	Cactus	S
12	2	Piano Tracks	Camel	D
13	3	Trench Glove Rake	Glove	S
14	2	House Chicken	Chicken	S
15	1	Door	Bread	D
16	2	Pencil Horse	Pencil	S
17	3	Suitcase Knife String	Tower	D
18	1	Plate	Plate	S

List 3

	Set Size	Memory Set Words	Test Word	Correct Response Same/Different
1	2	Nail Desk	Desk	S
2	3	Hammock Ape Carrot	Rug	D
3	1	Bridge	Bridge	S
4	3	Couch Broom Bug	Couch	S
5	1	Skate	Rope	D
6	2	Candle Banana	Candle	S
7	1	Ghost	Flag	D
8	2	Truck Bed	Drum	D
9	3	Net Rock Tractor	Tractor	S
10	2	Fan Book	Trumpet	D
11	1	Net	Net	S
12	3	Train Flower Moose	Parrot	D
13	1	Sword	Pan	D
14	3	Fiddle Canoe King	Fiddle	S
15	2	Basket Shoe	Basket	S
16	3	Rabbit Ball Tunnel	Parlor	D
17	2	Bird Watch	Dress	D
18	1	Arm	Arm	S

APPENDIX B

Instructions to Ss

Experiment I

All Ss heard the following introductory section:

"I'm going to show you some sets of words on this screen. Each set will have either one, two, or three words in it. After this set of words is removed from the screen, a short blank interval will appear, and then you'll see a single word which either is or is not a member of the set you saw just before. Your job is to say "yes" as quickly as you can if this word is a member of the set, or "no" if it's not." After it was clear that S understood the basic task, the following additional instructions were given in each condition:

Repetition

"I want you to repeat the words in each set to yourself while they are on the screen and during the blank period before the test word."

Separation Imagery

"For each word in the set I want you to make up a visual image of the thing that the word stands for. Keep the images separate so they don't interact in any way. For example, if there were three words in the memory set, you would make up an image for the first one on the left side of an imaginary screen, the image for the second would be in the middle, and the image for the third would be on the right. Hold your image by concentrating on it until the test word appears. Then you'd say 'yes' if the word represented one of the images you made up, or 'no' if it did not."

Original Interaction Imagery

"For each word in the set I want you to make up a visual image of the thing that the word stands for, and to put these images together in a single image. Hold your imaginary scene by concentrating on it until the test word appears. Then you'd say 'yes' if the word represented one of the images you made up, or 'no' if it did not."

New Interaction Imagery

The following section was added after the first sentence in the Original Interaction Imagery instructions above:

"Make sure that the objects in your scene are touching or overlapping. It is very important that you use your images as the basis for deciding if the test word was in the original set." Three examples of interaction images were shown to Ss in the form of line drawings at this point.

Sentence

"I want you to make up a sentence to yourself using the words in each set. When there are two words, make up a sentence where one thing is doing something to the other. When there are three words, use one of the words to tell how or where it was done with a prepositional phrase. When there is only one word in the set, simply repeat it to yourself."

At this point the task procedure was demonstrated: (1) Stars on the screen signalled the start of a trial; (2) the memory set appeared; (3) a blank interval followed; (4) the test word was shown, and S was to respond; and (5) stars were shown again on the screen to indicate the start of a new trial. All Ss were reminded of the strategy they were to employ during the actual task as four slow-paced example trials were given. Ss in the Original Interaction Imagery condition, the New Interaction Imagery condition, and the Sentence condition were asked to report the images or sentences they made up. Sentence Ss were given examples of sentences of suitable form for two item memory sets (e.g., "The knife cuts the hammer,") and for three item sets (e.g., "The ox pulls the stove on the sled"). Speed and accuracy in responding were stressed again, and any questions about the task were answered. It was emphasized that the trials themselves were not rapidly paced, and that ample time was allowed (in the Imagery and Sentence conditions) for making up images and sentences. Between blocks f trials, speed and accuracy were emphasized again, and Ss in all groups were reminded of the strategy they were supposed to use during the task.

APPENDIX C

RT Data from Experiment I

Median RT's are shown for each S for each set size (SS), response type (Y/N), and block (B) excluding practice trials. The data are listed as follows:

Column	Data
1	Condition Number
2	Sex: 1 = male, 2 = female
3	Vocal Speed
4	B2 SS1 Y
5	B2 SS1 N
6	B2 SS2 Y
7	B2 SS2 N
8	B2 SS3 Y
9	B2 SS3 N
10	B3 SS1 Y
11	B3 SS1 N
12	B3 SS2 Y
13	B3 SS2 N
14	B3 SS3 Y
15	B3 SS3 N
16	Identification Number for S

Sternberg Recognition Imagery
Repetition

1	1	31	37	42	49	52	59	49	35	38	35	45	50	51	30
1	1	33	44	41	53	49	53	55	38	42	50	41	44	53	36
1	1	39	47	53	56	60	60	53	42	59	53	63	48	63	40
1	1	28	36	62	72	49	55	56	43	51	43	52	65	55	10
1	1	35	58	45	55	47	58	52	43	39	45	48	51	53	45
1	2	29	44	44	46	49	53	52	38	44	48	49	52	65	28
1	2	36	43	48	56	54	56	56	45	44	52	47	48	50	24
1	2	36	43	54	57	44	59	61	40	47	54	54	60	66	20
1	2	32	34	44	67	45	60	54	48	47	49	55	65	61	5
1	2	32	50	38	55	52	55	55	40	43	48	41	50	53	15

Sternberg Recognition Imagery
Separation Imagery

2	1	27	40	51	62	53	64	58	41	63	50	55	58	57	43
2	1	18	32	35	34	44	33	44	28	37	37	34	42	43	42
2	2	38	60	56	73	65	60	66	55	49	65	59	68	51	7
2	2	32	62	62	69	58	61	62	55	59	61	55	82	63	13
2	2	33	39	44	49	47	56	46	40	43	41	50	53	46	23
2	2	29	34	33	46	42	44	46	31	37	34	42	46	43	32
2	2	38	37	38	43	40	49	43	33	34	36	38	51	44	35
2	1	24	30	35	38	37	48	51	38	35	35	41	43	48	26
2	1	24	28	35	33	37	43	45	30	39	37	38	32	43	9
2	1	31	50	59	60	54	59	60	55	52	60	56	63	60	17

Sternberg Recognition Memory
Interaction Imagery 1, Original

3	1	29	56	65	73	62	68	65	48	50	56	56	85	63	18
3	1	41	45	49	56	51	62	56	40	47	49	47	49	55	21
3	1	34	48	51	57	57	57	61	58	49	49	55	58	62	25
3	1	32	62	75	69	76	80	82	58	65	71	68	66	80	29
3	1	35	50	49	49	54	52	59	45	53	50	54	59	56	34
3	2	42	82	91	111	107	112	104	64	89	85	81	97	80	8
3	2	31	62	78	71	63	76	66	77	90	78	100	78	81	11
3	2	35	56	66	58	55	66	61	58	48	58	53	70	58	39
3	2	38	52	47	44	38	47	47	39	48	45	49	52	47	16
3	2	34	57	55	57	56	49	52	66	59	55	55	53	61	44

Sternberg Recognition Memory
Sentence

4	1	25	35	44	38	44	45	64	35	42	45	51	52	48	41
4	1	32	41	43	55	46	53	47	45	41	44	53	44	51	37
4	1	19	32	33	42	40	56	42	42	39	42	39	51	44	33
4	1	32	43	42	49	46	48	46	41	42	40	41	61	47	22
4	1	29	38	46	38	48	55	51	39	46	45	49	43	52	19

(continued)

4	2	37	57	55	55	64	52	67	48	49	50	50	53	58	31
4	2	32	50	40	56	38	51	49	43	43	43	45	52	43	27
4	2	38	43	44	51	38	53	57	37	39	43	41	43	41	14
4	2	31	53	47	56	48	66	54	46	50	51	45	65	53	12
4	2	48	60	56	64	58	74	70	60	58	62	63	76	86	6

Sternberg Recognition Memory
Interaction Imagery 2, New

5	2	35	45	44	62	53	61	65	42	47	52	48	44	58	1
5	2	31	62	51	52	56	65	57	45	49	55	49	57	53	2
5	2	31	59	52	58	53	55	57	61	52	55	58	68	57	3
5	2	29	48	60	60	53	60	59	54	48	50	57	53	61	4
5	2	36	45	62	53	55	62	61	57	45	56	59	61	58	5
5	1	31	58	52	56	50	55	65	48	56	52	70	64	55	6
5	1	32	39	42	41	45	49	54	42	39	47	48	51	55	7
5	1	27	45	53	59	56	60	61	36	44	48	45	53	57	8
5	1	34	64	63	68	55	73	57	47	46	48	45	55	50	9
5	1	36	50	58	59	49	53	49	62	47	50	53	51	50	10

APPENDIX D

Slope and Intercept Data from Experiment I

Slopes and intercepts for individual Ss for "yes" and "no" responses based on either SS1,2,3 or SS1 and 2 are listed as follows:

Column	Data	
1	Condition Number	
2	Sex: 1 = male, 2 = female	
3	Identification Number for S	
4	Slope Yes	
5	Intercept Yes	
6	Slope No	SS 1,2,3
7	Intercept No	
8	Slope Yes	
9	Intercept Yes	SS 2,3
10	Slope No	
11	Intercept No	

ANOVA on Slopes Sternberg

Cond 5Sex 2
Cond 1 = Repetition
Cond 2 = Separation Imagery
Cond 3 = Interaction Imagery
Cond 4 = Sentence
Cond 5 = Interaction Imagery New Data
Sex 1 = Male
Sex 2 = Female

					SS 1,2,3			SS 2 and 3		
1	1	36	3.9	38.9	5.8	35.0	-0.6	51.2	7.4	31.0
1	1	40	5.0	44.1	.5	58.5	5.3	43.5	-1.0	62.5
1	1	10	2.3	51.8	4.3	51.5	6.2	41.4	5.6	39.9
1	1	30	9.0	27.7	4.4	38.0	10.0	25.3	-1.3	53.5
1	1	45	4.5	41.4	4.0	39.8	6.8	35.0	4.7	38.1
1	2	28	5.	36.8	6.2	38.4	6.9	32.8	8.8	31.6
1	2	24	6.3	39.0	3.5	43.8	-1.1	59.0	-0.5	54.5
1	2	20	8.3	36.2	4.6	44.9	2.4	52.2	14.6	18.4
1	2	5	8.4	36.9	6.8	38.0	3.8	49.3	5.2	42.1
1	2	15	5.0	39.0	5.6	35.6	1.3	49.1	8.3	28.5
2	1	42	6.1	24.6	3.9	31.6	5.8	25.5	3.6	32.3
2	1	26	5.6	27.8	7.6	26.0	8.0	21.6	11.5	15.8
2	1	17	6.2	48.9	2.4	51.3	2.6	58.5	5.5	43.1
2	1	9	1.0	33.6	4.5	29.5	-0.5	37.6	6.5	24.1
2	1	43	10.9	31.4	00.0	57.1	8.1	38.8	5.6	42.1
2	2	7	3.2	55.4	2.5	50.1	-1.5	68.5	-2.0	62.5
2	2	23	5.9	34.5	1.7	45.2	7.6	29.8	-9.1	74.3
2	2	32	7.4	26.6	4.7	31.7	7.8	25.5	4.5	32.5
2	2	35	6.9	27.2	3.5	32.0	11.2	15.8	2.2	35.6
2	2	13	8.0	50.6	1.0	59.3	16.5	28.1	3.0	54.0
3	1	34	2.3	46.9	2.9	48.7	4.2	41.8	4.0	46.0
3	1	25	2.4	49.3	4.6	46.8	4.0	45.1	5.0	45.8
3	1	29	4.9	56.5	5.5	64.0	4.0	59.0	4.7	66.1
3	1	21	4.5	41.7	3.1	44.5	00.5	52.6	3.5	43.6
3	1	18	11.3	40.4	5.3	47.9	13.0	36.0	8.0	40.8
3	2	44	-6.2	68.3	00.0	58.4	-4.5	63.9	3.6	49.2
3	2	16	-0.9	54.5	00.5	45.1	-3.3	61.0	5.3	32.5
3	2	39	2.5	57.8	1.0	54.7	00.5	63.1	6.1	41.1
3	2	11	4.0	68.0	-2.1	80.6	-2.9	86.2	-3.9	85.3
3	2	8	9.7	70.7	00.2	92.4	-0.7	99.2	-3.0	101.3
4	1	19	5.0	34.1	1.9	43.9	5.5	32.8	1.3	45.5
4	1	22	7.0	32.5	1.8	40.2	11.5	20.4	3.1	36.6
4	1	33	5.5	34.5	3.7	31.8	10.3	21.6	4.6	29.5
4	1	41	6.3	31.2	6.5	36.4	1.6	43.9	5.1	40.2
4	1	37	4.2	39.0	3.3	40.1	3.3	41.5	00.0	49.0
4	2	6	7.5	50.0	11.2	44.4	10.5	42.5	15.6	52.5
4	2	12	9.0	36.3	00.7	49.1	13.8	23.6	3.3	42.1
4	2	14	3.8	38.0	5.9	33.1	-0.8	50.5	13.3	13.3
4	2	27	2.5	46.7	-9.9	71.3	3.8	43.1	6.1	28.5
4	2	31	1.7	50.2	6.6	42.5	5.0	41.0	9.4	34.9

5	1	10	-1.1	57.5	-0.5	51.6	-3.1	62.8	-1.6	54.5
5	1	9	4.7	48.4	-1.0	53.8	6.1	44.6	2.8	43.6
5	1	8	8.3	32.9	5.0	42.6	6.0	39.1	7.5	36.1
5	1	7	5.1	35.0	6.3	34.9	3.0	40.8	8.5	29.1
5	1	6	00.9	53.7	2.8	51.6	3.3	47.3	00.8	57.0
5	2	1	5.2	40.3	7.4	37.5	-1.0	57.0	9.5	32.0
5	2	5	3.8	46.3	1.4	53.9	5.8	41.0	00.8	55.5
5	2	4	00.0	54.4	3.4	49.3	2.5	48.0	5.0	45.1
5	2	3	00.0	58.6	1.6	52.2	3.8	48.1	1.5	52.6
5	2	2	7.8	44.8	00.9	52.0	10.3	38.1	1.1	51.3

APPENDIX E

Lists of Memory Set Pictures and Test Stimulus Pictures

Experiment II

Practice List

	Set Size	Memory Set Pictures	Test Picture	Correct Response Same/Different
1	1	Witch	Chair	D
2	2	Log Man	Pillow	D
3	1	Bell	Carrot	D
4	2	Cake Radio	Cake	S
5	1	Rope	Rope	S
6	1	Hat	Cup	D
7	2	Fan Book	Fan	S
8	2	Belt Wheel	Puzzle	D
9	1	Baseball Bat	Baseball Bat	S

List 1

	Set Size	Memory Set Pictures	Test Picture	Correct Response Same/Different
1	2	Truck Bed	Bed	S
2	2	Sock Airplane	Iron	D
3	1	Gift-box	Gift-box	S
4	1	Bridge	Sled	D
5	2	Pie Fork	Bird	D
6	1	Lamp	Lamp	S
7	2	Basket Shoe	Bread	D
8	2	Mountain Elephant	Elephant	S
9	1	Table	Tire	D
10	2	Tie Moon	Tie	S
11	2	Gun Spoon	Eye	D
12	1	Boy	Dollar Bill	D
13	1	Pipe (smoking)	Pipe	S
14	2	Hammer Knife	Knife	S
15	1	Star	Football	D
16	2	Pan Fire	Pan	S
17	1	Pumpkin	Sword	D
18	1	Whale	Whale	S
19	2	Fish Soldier	Rake	D
20	1	Purse	Purse	S

List 2

	Set Size	Memory Set Pictures	Test Picture	Correct Response Same/Different
1	1	Boat	Boat	S
2	2	Drinking-glass Telephone	Monkey	D
3	1	Boot	Cardboard Box	D
4	1	Hatchet	Hatchet	S
5	2	Leaf Duck	Clock	D
6	2	Horse Pen	Net	D
7	1	Arm	Arm	S
8	2	Nail Desk	Nail	S
9	1	Door	Doughnut-shaped object	D
10	2	Bicycle Knee	Bicycle	S
11	2	Rabbit Ball	Teeth	D
12	1	Roller Skate	Turkey	D
13	1	Hand	Hand	S
14	2	House Chicken	Finger-ring	D
15	2	Railroad tracks Piano	Piano	S
16	1	Snake	Camel	D
17	2	Girl Lion	Girl	S
18	1	Kite	Kite	S
19	1	Safety Pin	Top	D
20	2	Cat Apple	Apple	S

APPENDIX F

Paired-Associate Test Made from Set Size Two Picture Pairs

Experiment II

	Stimulus	Correct Response
1	Rabbit	Ball
2	Gun	Spoon
3	Girl	Lion
4	Moon	Tie
5	Basket	Shoe
6	Horse	Pen
7	Railroad Tracks	Piano
8	Nail	Desk
9	Fish	Soldier
10	Mountain	Elephant
11	Truck	Bed
12	Cat	Apple
13	Leaf	Duck
14	Sock	Airplane
15	Pan	Fire
16	House	Chicken
17	Pie	Fork
18	Bicycle	Knee
19	Hammer	Knife
20	Glass	Telephone

APPENDIX G

Instructions to Ss

Experiment II

All Ss heard the following introductory section:

"I'm going to show you some pictures on this screen, and each picture will have either one or two objects in it. After a picture goes off the screen, there will be a short blank period, and then a picture of a single object will appear. Your job is to say "yes" as quickly as you can if this object was included in the picture you just saw, and to say "no" as quickly as possible if it was not."

At this point the task was demonstrated to Ss in the Control and Provided Interaction conditions as in Experiment I. Ss in the S-generated interaction condition were told to make up interacting images where one object was doing something to another or was in a particular spatial relationship to it when there were two items in the memory set. Three examples of line drawings of such images were shown (e.g., an owl inside a jar), and it was stressed that the objects in the image should be touching or overlapping. The task was then demonstrated as in Experiment I, with Ss reporting the interactive images which they made up to E. Ss in the Control and Provided Interaction conditions were told to attempt to maintain the memory set object(s) in memory by visualizing them and focusing their eyes on a dot centered in the screen. Ss in the S-generated interaction condition were told to center the visual interactions which they made up on the dot in the center of the screen during the blank period. Speed and accuracy in responding were emphasized, and Ss were informed that the task itself was not presented at a particularly fast rate. Questions about the task were answered at this time. Between blocks of trials, speed and accuracy were stressed, as well as the making up of interactions in the S-generated Interaction condition. Instructions concerning the dot on the screen were also repeated.

After the memory scan task was completed, Ss were given the following instructions. "There is something else that I'd like you to do. Remember the times when two objects were shown together in a picture? I'm going to read you the name of one of the objects in each pair, and you'll try to tell me the name of the one that went with it. Ready?" The self-paced PA recall task was given when it was clear that S understood what was required.

APPENDIX H

Data from Experiment II

Individual Ss' slopes, intercepts, and median RT's for each block (B), set size (SS), and response type (Y/N). Practice trials are excluded. PA scores are also shown. The data are listed as follows:

Column	Data
1	Condition Number
2	Identification Number for S
3	Sex: 1 = male; 2 = female
4	Slope Yes
5	Intercept Yes
6	Slope No
7	Intercept No
8	PA Scores
9	B1 SS1 Y
10	B1 SS2 Y
11	B2 SS1 Y
12	B2 SS2 Y
13	B1 SS1 N
14	B1 SS2 N
15	B2 SS1 N
16	B2 SS2 N

Experiment 2 - Memory Scan for Pictures Control

Sex 2
Sex 1 = Male
Sex 2 = Female

1	27	1	5.9	39.7	1.0	45.1	0	45	49	49	54	44	45	43	49
1	9	1	2.7	33.3	4.9	34.6	2	36	40	34	37	43	47	39	42
1	23	1	3.6	42.4	6.1	42.3	1	48	45	45	51	48	52	49	56
1	00	1	3.4	31.8	-.8	38.1	2	35	38	36	39	35	35	37	38
1	21	1	2.0	40.5	9.2	31.1	7	41	47	41	38	40	49	42	42
1	28	2	11.1	30.7	4.5	44.6	11	48	53	40	47	57	56	45	50
1	11	2	8.2	27.6	1.9	37.9	6	33	46	37	41	39	42	40	42
1	8	2	-2.3	57.3	2.9	48.4	4	54	54	56	50	54	47	45	50
1	3	2	9.4	40.2	-.6	54.1	6	57	67	44	53	57	56	46	39
1	4	2	10.0	25.5	1.8	34.2	6	35	47	35	43	36	42	38	36

Experiment 2 - Memory Scan for Pictures Provided Interaction

Sex 2
Sex 1 = Male
Sex 2 = Female

2	13	1	18.7	22.8	8.1	43.3	9	43	58	40	58	54	57	48	57
2	16	1	5.9	58.2	2.2	59.5	11	68	70	62	78	81	61	59	61
2	19	1	-8.8	78.3	-8.8	76.3	8	64	62	75	60	64	60	65	68
2	24	1	5.5	39.1	1.4	46.3	18	43	48	41	53	47	46	48	56
2	2	1	18.9	25.1	1.8	46.2	16	38	68	38	45	49	46	46	53
2	26	2	10.2	23.4	3.2	34.7	14	35	46	30	39	39	45	36	38
2	30	2	4.3	39.2	3.5	47.7	13	45	46	2	52	54	54	49	56
2	10	2	2.6	46.2	5.4	49.6	18	52	59	46	45	60	66	51	58
2	14	2	10.5	50.8	3.3	63.8	5	62	73	61	72	74	75	68	69
2	6	2	-2.5	63.7	-1.5	68.5	13	58	57	57	65	62	65	71	66

Experiment 2 - Memory Scan for Pictures S-generated Interaction

Sex 2
Sex 1 = Male
Sex 2 = Female

3	1	1	6.4	25.4	1.1	34.7	14	33	38	30	37	36	38	36	35
3	5	1	7.2	27.4	2.1	33.0	9	34	40	35	45	33	31	36	42
3	7	1	14.4	25.5	.8	35.8	17	36	53	37	55	35	41	38	38
3	12	1	4.2	40.2	2.7	37.0	12	43	48	46	53	39	46	39	42
3	17	1	14.1	18.2	3.5	38.7	13	34	44	30	49	42	43	41	47
3	15	2	6.3	34.3	8.6	35.6	17	39	46	46	50	46	50	44	50
3	20	2	-1.3	57.2	7.8	41.5	11	55	52	53	57	51	60	47	54
3	22	2	-.9	62.6	9.6	48.9	9	68	59	53	61	60	77	57	61
3	25	2	6.0	54.6	5.5	37.3	14	39	51	38	40	52	43	39	56
3	29	2	-.9	59.1	6.0	46.4	9	55	56	56	65	51	61	54	54

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