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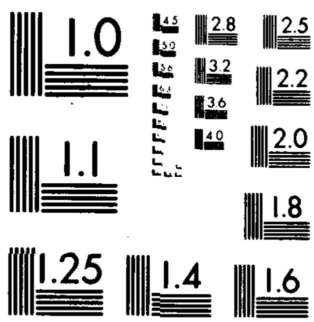

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Individual Differences in Secondary Task Performance

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Reaction time (RT) to secondary probes that occurred during the rehearsal period of an easy memory task were used to measure individual differences in spare capacity associated with the memory task. This measure was used to predict performance on a harder version of the memory task. Two memory tasks were investigated, one verbal and one spatial. The verbal task required subjects to recall letter-digit pairs.

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The spatial task involved recognition of random patterns. Probe RT was sensitive to the difficulty of the verbal memory task, and an analysis of individual differences showed that probe RT during the easy version of the verbal task was correlated with performance on a harder version of the same task. Probe RT was less sensitive to the demands of the spatial memory task, and for that task, the "easy-to-hard" correlation was not significant. It was concluded that capacity limitations were a determining factor in performance on the verbal but not the spatial task.

Abstract

Reaction time (RT) to secondary probes that occurred during the rehearsal period of an easy memory task were used to measure individual differences in spare capacity associated with the memory task. This measure was used to predict performance on a harder version of the memory task. Two memory tasks were investigated, one verbal and one spatial. The verbal task required subjects to recall letter-digit pairs. The spatial task involved recognition of random patterns. Probe RT was sensitive to the difficulty of the verbal memory task, and an analysis of individual differences showed that probe RT during the easy version of the verbal task was correlated with performance on a harder version of the same task. Probe RT was less sensitive to the demands of the spatial memory task, and for that task, the "easy-to hard" correlation was not significant. It was concluded that capacity limitations were a determining factor in performance on the verbal but not the spatial task.

Individual Differences in Secondary Task Performance[1]

This article is concerned with performance on a dual task in which one component is designated as primary and the other as secondary. Suppose that there is something analogous to "mental energy", an attentional resource that is required for a variety of tasks (Kahneman, 1973). If two tasks are performed concurrently, with one designated as primary, and the other secondary, then the resource demands of the primary task should be fulfilled first. Therefore, secondary task performance should provide a measure of the spare capacity not required by the primary task (Kerr, 1973). Secondary task performance should decrease as the capacity demands of the primary task increase. The most common uses of secondary task measures have been to compare the demands of various stages in the execution of a primary task (e.g. Johnston, Greenberg, Fisher, & Martin, 1970; Logan, 1978; Posner & Boies, 1971), and to compare the demands of the same primary task under various conditions (e.g. Britton, Westbrook, & Holdredge, 1978 ; Martin, 1970). Another use of secondary task measures has been to differentiate among individuals who vary in skill on the primary task. Those individuals who are highly skilled on the primary task should require a smaller proportion of their total resources to perform the task, and should therefore have more spare capacity available to perform the secondary task. This use of secondary task measures has been reported more often in the applied than in the experimental literature (e.g. Brown, 1968).

The assertion that primary and secondary tasks compete for mental resources has a further implication for individual differences in secondary task performance. Secondary task measures associated with an easy version of the primary task should predict performance on a harder version of the same primary task. Consider two people, one skilled at primary task performance and the other less skilled. If both are performing the primary task at a low level of difficulty, they may both achieve virtually perfect performance. Presumably, though, the less skilled individual is using more mental resources to achieve the same level of primary task performance. Thus the two persons will perform at different levels on a secondary task. If this is the case, secondary task performance when the primary task is easy should predict primary task performance at a higher level of difficulty. We shall refer to this prediction as the " easy-to-hard prediction". The main purpose of the research reported here was to test the validity of the easy-to-hard prediction in several dual task situations in which the primary component was a memory task and the secondary component was a probe reaction time task.

Easy-to-hard prediction is based on a simple model of dual-task performance. According to this model, each subject has a fixed supply of mental resources. Primary and secondary tasks compete for these resources, and performance on each task improves as more resources are devoted to it. During the dual task involving the easy version of the primary task, subjects allot enough resources to the primary task to perform that task adequately, and devote their remaining resources to the secondary task. Thus secondary task performance can be used as a measure of spare capacity; i.e. capacity not required by the easy version of the primary task. Individual differences in secondary task performance should reflect individual differences in spare capacity, and hence should identify people who will do well or poorly when the primary task becomes harder. The assumptions underlying this prediction are that the hard version of the primary task requires more resources than the easy version and that an individual's performance on the hard version of the primary task is limited by total available resources. Those individuals who have more spare capacity during the easy version of the primary task should have more resources available to meet the increased resource demands of the primary task, and should thus perform the task at a higher level. Hence performance on the secondary task during the easy version of the primary task should be positively correlated with performance on the hard version of the same primary task.

In the research reported here, certain issues concerning how subjects divide their mental resources between two competing tasks were ignored. Specifically, we were not concerned with the question of whether processes required by the two tasks could actually be carried out simultaneously, or whether subjects switched back and forth between the two. However, we were concerned that interference between pairs of tasks could be attributed to central, not peripheral interference. Particular care was taken to avoid interference resulting from simultaneous response demands.

Verbal and spatial short-term memory tasks were used as the primary tasks. The verbal memory task was a continuous paired associate learning task similar to that used by Atkinson and Shiffrin (1968). The spatial task involved holding in memory a random pattern of plus signs. In all cases, the secondary task required the subject to make a simple response to a visual or auditory stimulus. The stimulus for the secondary task could occur only during the rehearsal period of the primary task. The subject was never required to respond to the two tasks during the same interval, and response interference was avoided.

The pattern of interference manifested in secondary probe RT may depend on the exact type of secondary probe task employed (McLeod, 1977; in press;

Schwartz, 1976). Consequently, we combined the verbal memory task with two quite different probe tasks. The first, which required a manual response to a visual probe, was selected to involve specific resources as distinct as possible from those involved in rehearsal of verbal material. The second, which required a vocal response to an auditory probe, was selected to involve the same auditory-vocal system utilized by verbal rehearsal (Baddeley, 1976). If interference between the verbal memory task and the probe task involves competition for a specific system, then only the auditory-vocal task should be sensitive to the demands of the verbal memory task. But if interference reflects demands on a more general resource pool, then both probe tasks should vary with the demands of the verbal memory task.

The first experiment, which did not involve analysis of individual differences, was intended to establish that the paired associate task and the two probe tasks did indeed compete for resources. In the second and third experiments, the validity of easy-to-hard prediction was tested using paired associate learning as the primary task. Experiment 2 involved the visual-manual probe task, and Experiment 3 involved the auditory-vocal probe task. In Experiment 4, the easy-to-hard prediction technique was extended to the spatial memory task.

Experiment 1

Subjects

Subjects were 20 male and 16 female freshmen at the University of Washington. Each subject participated for four 1-hour sessions and was paid $3.00 per hour.

Apparatus

Presentation of stimuli and recording of responses were under the control of a Data General Corporation NOVA 3 computer. Visual stimuli were presented on Tektronix 604 oscilloscopes. Tones were generated by a Wavetek Waveform Generator, Model 159-002, and presented through Telephonics TDH-49P headphones. One to six subjects were run simultaneously in separate soundproofed booths. Each was seated in front of a 10X13 cm oscilloscope screen with fingers resting on eight push-button style response keys. The rate of progress of each subject through the task was independent of the progress of other subjects.

Tasks

Primary task. The primary task was a continuous paired associate recall task in which subjects kept track of 2, 3, 4, 5, or 7 letter-digit pairs. A typical sequence of events for the two-pair condition is illustrated in Table 1. The subject initiated the block by pressing a key. Then each of the letters appeared for 3 seconds paired with a randomly chosen digit (e.g. "A = 3"). After this initial presentation of all letter-digit pairs, each trial consisted of a question involving one of the letters (e.g."A = ?"), followed by a new pair involving that same letter (e.g. "A = 4"). On each trial, the letter to be queried was chosen randomly from the entire set.

The correct response to a question was the number with which the letter had last been paired. Subjects responded by pressing one of eight numbered keys. After the response, a 1-second feedback message ("Right" or "Wrong") appeared on the screen. If a subject failed to respond for 10 seconds, the message "Too Slow" appeared on the screen and an error was recorded. Following the feedback message a new pair was presented. The letter just queried was paired with a new digit, which was randomly chosen from the digits 1 to 8 with the restriction that it could not be the same as the digit last paired with that letter. The new pair remained on the screen for a 3 second rehearsal interval, and was followed by the question for the next trial. Each subject had a

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Insert Table 1 about here

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different sequence of letter-digit pairs.

At the end of each block, subjects received feedback concerning the percent of digits they had recalled correctly.

Secondary task. In the secondary task the subject responded as quickly as possible to a probe stimulus presented during the rehearsal interval. The visual probe consisted of four asterisks which appeared immediately above a letter-number pair. The auditory probe was a tone presented to the subject through headphones. Subjects responded to visual probes by pressing any of the eight keys. They responded to auditory probes by saying the syllable "Bop" into a microphone.

Probes were always presented during the rehearsal interval for a new pair (never during a question), so that the subject was never required to respond to two tasks during the same interval. No probes occurred during the initial presentation of pairs in a block. An equal number of probes occurred at 500, 1000, and 1500 msec following the onset of a new letter-digit pair. Probes were presented on three-fourths of the trials in a block. The order of probe and no-probe trials was independently randomized for each subject, as was the order of the three probe intervals.

The probe was removed as soon as the subject responded, or after 1500 msec if no response occurred. Subjects did not receive feedback concerning probe RTs.

Procedure

The experiment was conducted on four consecutive days, one hour per day. During the first day, subjects were acquainted with all the conditions of the experiments, but no data was recorded. Each of the following three days was devoted to one of three conditions: Primary Task Alone, Primary Task with Visual Probes, or Primary Task with Auditory Probes. The 36 subjects were divided into six groups of six subjects each, and each of these groups received one of the six possible orders of the three conditions.

Primary Task Alone. In this condition, subjects received the continuous paired associate task alone; no probes were presented. There were five blocks of 36 trials each. During each block, subjects kept track of either 2, 3, 4, 5, or 7 letter-digit pairs. The order of blocks was counterbalanced across the six groups.

Primary Task with Visual Probes. In this condition, subjects performed both the paired associate and the visual probe tasks. There were six blocks of trials, one each for 2, 3, 4, 5, and 7 pairs, and an additional secondary task control condition during which subjects ignored the letter-digit pairs and responded only to the probes. During the control condition, questions and new pairs occurred just as in the other blocks, but the question was removed after 1 second and the subject was not required to respond to it.

Primary Task with Auditory Probes. In this condition, subjects performed both the paired associate and the auditory probe task. In all other respects, this condition was identical to the Primary Task with Visual Probes condition.

Results

Probe RT

For each subject, mean RT to the probe was computed for each condition. Mean RTs across subjects are shown in Figure 1. Each point in Figure 1 is based on approximately 27 data points per subject. (Subjects failed to respond to .5% of the auditory probes and .8% of the visual probes.) The RT data were analyzed using a repeated measures analysis of variance (ANOVA) in which the within subjects factors were memory load (0, 2, 3, 4, 5, or 7 pairs) and probe task (manual response to a visual probe or vocal response to an auditory probe). The main effect of memory load was significant ($F(5, 175) = 71$, $MS_e = 4832$; $p < .001$), as were the main effect of probe task ($F(1, 35) = 22$, $MS_e = 24000$, $p < .001$), and the interaction ($F(5, 175) = 4.5$, $MS_e = 3315$, $p < .001$). Responses to the probe were longer when subjects were maintaining larger memory loads, and were longer for the visual-manual probe task than the auditory-vocal probe task. RTs to the visual-manual probe task increased more sharply with memory load than RTs to the auditory-vocal probe task.

Insert Figure 1 about here

The difference between RT in the control condition and RT in the various memory load conditions was much greater than the differences among the various memory load conditions. In order to find out whether difficulty of the primary task significantly affected probe RT, a second ANOVA was done omitting the control condition. This analysis provides a stronger test of the assertion that primary and secondary tasks compete for resources (Roediger, Knight, & Kantowitz, 1977). Again, both main effects and the interaction were significant (for memory load, $F(4,140) = 10.5$, $MS_e = 3826$, $p < .001$; for probe task, $F(1,35) = 21$; $MS_e = 26,538$, $p < .001$; for the interaction, $F(4,140) = 2.7$, $MS_e = 3067$, $p < .05$).

RTs from the visual-manual and auditory-vocal probe tasks were also analyzed separately. For these analyses, RT in the secondary task control conditions was again omitted. In the case of the visual-manual probe task, the effect of memory load was significant, $F(4,140) = 9.9$, $MS_e = 3728$, $p < .001$. Paired comparisons among the means showed that RT in the two- and three-item memory load conditions was significantly faster than RT in the five- and seven-item conditions ($p < .001$, Duncan's Multiple Range Test). In the case of the auditory-vocal probe task, the effect of memory load was also significant, $F(4,140) = 3.7$, $MS_e = 3165$, $p < .01$. In this case, however, only the difference between RT in the two-item condition and RT in the four- and five-item conditions was significant ($p < .05$).

Recall

For each subject, proportion of items correctly recalled was computed for each condition. Mean recall scores across subjects are shown in Figure 2. Recall data were analyzed using a repeated measured ANOVA in which the within subjects factors were memory load (2, 3, 4, 5, or 7 items) and probe task (no-probe control, visual-manual probe task, or auditory-vocal probe task). Both main effects and the interaction were significant (for memory load, $F(4, 140) = 202$, $MS_e = .016$, $p < .001$; for probe task, $F(2,70) = 19$, $MS_e = .021$; $p < .001$; for the interaction, $F(8,280) = 4.8$, $MS_e = .008$, $p < .001$). Mean proportion of items recalled in the three probe task conditions was compared using Duncan's Multiple Range Test.

For these tests, recall scores were summed over the five memory load conditions. Recall was significantly better in the control condition than in either the visual-manual or the auditory-vocal probe task conditions ($p < .001$), but there was no significant difference between recall scores during the two types of probe tasks.

Insert Figure 2 about here

Discussion

If probe RT is to be used as a measure of spare capacity associated with the paired associate primary task, then there must be evidence that the two tasks compete for mental resources. Experiment 1 provided such evidence. For both probe tasks, RT increased markedly from the control condition to the dual-task conditions. Furthermore, RT increased as the demands of the paired associate task were increased. Thus the experiment supported the assertion that the primary paired associate task and the two secondary probe tasks compete for mental resources.

Ideally, if a secondary task is to serve as a measure of spare capacity, then performance on the primary task should be unaffected by the introduction of the secondary task (Kerr, 1973). In practice, however, this condition is rarely met. Although subjects are instructed not to allow the secondary task to interfere with performance of the primary task, it is common to find a decrement in primary task performance in the dual-task conditions as compared to a control condition. Such a decrement occurred in this experiment. Summed over all memory load conditions, proportion of items correctly recalled dropped from .84 in the control condition to .78 in the Visual Probe Condition and .75 in the Auditory

Probe Condition. Although significant, the drop was not large, and does not negate the validity of the probe task as a measure of spare capacity.

An interesting result of this experiment was that the visual-manual probe task was more sensitive to the demands of the primary task than was the auditory-vocal probe task. This ran counter to our intuitions that the auditory-vocal probe task and verbal rehearsal would compete for a common system. The finding can be explained within a general resource model of attention by supposing that the primary task and both secondary tasks draw from the same common resource pool, but that the two secondary tasks have different performance-resource functions(Norman & Bobrow, 1975). Performance on the visual-manual probe task declines more rapidly than performance on the auditory-vocal task as resources are removed. The data do not support the idea that subjects allotted more resources to the auditory-vocal task than to the visual-manual task, since primary task performance was not significantly better during the visual-manual than the auditory-vocal probe task.

Finally, it should be noted that for both secondary tasks, probe RT increased much more from the control condition to the two-item memory load than from the two-item load to the seven-item load. It is a common finding in the dual-task literature that there is a large decrement in secondary task performance from control to dual-task conditions, but little or no change with increasing difficulty of the primary task (Wickens, in press). One explanation, proposed by Kantowitz and Knight (1976) and Navon and Gopher (1979) is that coordinating the two tasks demands resources beyond the requirements of each individual task. Thus the decrement in secondary task performance between control and dual-task conditions reflects not only the demands of the primary task, but the additional demands of coordination.

Experiments 2 and 3

Experiment 1 demonstrated that probe RT does reflect the difficulty, and thus presumably the resource demands, of the continuous paired associate primary task. It was therefore reasonable to suppose that probe RT would also reflect differences between individuals in the spare capacity associated with the paired associate task. Experiments 2 and 3 were designed to test the validity of the easy-to-hard prediction, i.e. to discover whether probe RT during an easy (two-item load) version of the paired associate task would predict performance on a much harder (seven-item load) version of the same task.

Experiment 2 involved the visual-manual probe task and Experiment 3 the auditory-vocal task. In each case, subjects performed the probe task in a control condition where they were not asked to recall the letter-digit pairs, and during the rehearsal periods of both the easy and the hard versions of the paired associate task. RT to the probe during the easy paired associate task was taken to be a measure of the spare capacity available to the individual during this task. This measure was then correlated with performance on the harder version of the paired associate task when performed alone. In order to control for individual differences in speed of responding to the probe alone, RT in the control condition was partialled out.

The design of experiments investigating differences between subjects is necessarily quite different from the design of experiments investigating general effects across subjects. It is necessary that enough observations be obtained so that the mean observation for each individual in each condition is a reliable estimate of that subject's ability. For this reason, the number of conditions was reduced from 17 in Experiment 1 to only five each in Experiments 2 and 3. To assure that measures were comparable across subjects, the order of conditions was the same for each subject. Thus these experiments did not utilize a completely counterbalanced design. Finally, in an effort to control motivation, rewards were offered for good performance.

Method

Subjects

Twenty-four male and 24 female freshmen at the University of Washington served as subjects in Experiment 2. In Experiment 3 there were 24 males and 26 females. In each case, subjects were selected on the basis of verbal ability. Washington State high school students who plan to apply for admission to the University of Washington take the Washington Pre-College Test in their junior year. The distribution of Verbal Composite scores in the freshman class at the University of Washington was divided into sixths. Approximately four men and four women from each sixth were recruited as subjects in these experiments.

Subjects were paid $8.00 for participation in two 1½-hour sessions. Bonus points were awarded on the basis of performance in the experimental tasks, and each subject received a bonus payment based on points earned.

Primary and Secondary Tasks

The tasks were the same as in Experiment 1 with the following exceptions: a) each experiment involved only one type of probe task: for Experiment 2, manual response to a visual probe, and for Experiment 3, vocal response to an auditory probe; b) there were only two levels of the primary task; subjects were required to keep track of two or seven letter-digit pairs.

Procedure

Subjects were tested on two days. On both days there was one block of 48 trials for each of the five conditions listed below.

Secondary Control. Subjects were instructed to ignore the letters and numbers and respond only to the probe stimuli. Letter-number pairs and questions appeared exactly as in other conditions, but questions remained on the screen for only 1 second. Bonus points were based on mean RT to probes.

Easy Recall-No Probes. Subjects were required to keep track of two pairs. No secondary probes occurred. Points in this condition were based on percentage of letter-digit pairs correctly recalled.

Easy Recall with Probes. The easy version of the paired-associate task was combined with the secondary RT task. Subjects were instructed that the recall task was more important than the RT task. Points in this condition were based on percent recall and mean RT to probes, with twice as many points possible for recall.

Hard Recall-No Probes. Subjects were required to keep track of seven pairs. No secondary probes appeared. Points were based on percentage of items correctly recalled.

Hard Recall with Probes. The hard version of the paired-associate task was combined with the secondary RT task. Points were based on percentage of items correctly recalled and mean RT to probes, with twice as many points possible for recall.

The order of conditions was identical for all subjects, and is shown in Table 2.

Insert Table 2 about here

Results and Discussion

The results of Experiments 2 and 3 will be presented separately. For each experiment, group results summed over individual subjects will be presented first, followed by correlational analyses of individual differences.

Experiment 2

Group results. Seven measures were computed for each subject: Mean RT in the control, easy recall, and hard recall conditions, and proportion of items correctly recalled in the easy recall alone, easy recall with probes, hard recall alone, and hard recall with probes conditions. These measures were summed across the two days of the experiment. Mean RT summed over all 48 subjects is shown in Figure 3. Mean recall accuracy is shown in Figure 4.

Insert Figure 3 about here

Insert Figure 4 about here

As in Experiment 1, there was a much greater increase in probe RT from the control to the easy recall condition (192 msec) than from the easy to the hard recall condition (35 msec). An ANOVA showed the effect of recall condition on probe RT to be significant, $F(2,94) = 125$, $MS_e = 5717$, $p < .001$. Planned orthogonal comparisons revealed that probe RT was shorter in the control condition than in the easy and hard recall conditions combined, $t(94) = 15.7$, $p < .001$, and probe RT was shorter in the easy recall condition than in the hard recall condition, $t(94) = 2.27$,

$p < .05$. However, since the order of conditions was the same for all subjects on both days (control-easy-hard), these effects were confounded with practice.

Recall was much less accurate in the seven-item condition than in the two-item condition. Proportion of items correctly recalled was above .9 in the two-item conditions and near .5 in the seven-item conditions ($F(1,47) = 709$, $MS_e = .011$, $p < .001$). As in Experiment 1, the probe task interfered somewhat with recall, as indicated by the fact that proportion of items correctly recalled was lower in the probe than the no-probe conditions ($F(1,47) = 32$, $MS_e = .003$, $p < .001$). The interaction between difficulty of the paired associate task and the probe-no probe factor was also significant ($F(1,47) = 7.0$, $MS_e = .002$, $p < .05$), indicating that the probe task interfered slightly more with the hard than the easy version of the paired associate task.

Individual differences. The correlations among the experimental measures are presented in Table 3. Reliabilities, shown in the diagonal, are based on correlations between measures from Day 1 and Day 2, corrected for length using the Spearmen-Brown Formula.

Insert Table 3 about here

Of primary interest are the correlations involving accuracy of recall in the hard paired associate task done alone. First notice that RT in the control condition, which should be independent of the demands of the memory task, was uncorrelated with hard recall accuracy, $r = -.05$. However, RT in the easy recall condition, which should reflect the spare capacity associated with easy recall, was significantly correlated with accuracy of recall in the hard condition, $\underline{r} = -.40$, $p < .01$. (The negative correlation means that fast RTs were associated with good recall scores.) This correlation is consistent with the hypothesis that spare capacity in the easy condition predicts performance in the hard condition.

We can think of RT to the probe during the easy memory task as being made up of two components, time to respond to the probe alone, and a delay attributable to the demands of the paired associate task. Only the delay component should reflect the spare capacity associated with the recall task. If delay is long, then presumably the subject had little spare capacity available during the paired associate task; if it is short, the subject had more spare capacity available. Ideally, we would like to remove from the probe RT measure the variability associated with individual differences in responding to a signal in isolation, and look only at the delay attributable to the paired associate task. One way to do this is to compute the correlation between probe RT and hard recall, partialling out the variance associated with control RT. This partial correlation was -.44, $p < .01$. Thus even when the variability associated with control RT was removed, RT in the easy recall condition was significantly correlated with the accuracy of recall in the hard condition.

<u>Experiment 3</u>

<u>Group results</u>. The design of Experiment 3 was identical to that of Experiment 2, except that the probe task involved a vocal response to an auditory probe. As in Experiment 2, three RT and four recall measures were computed for each subject. Mean RT measures are shown in Figure 3 and mean recall measures in Figure 4.

As in Experiment 2, RT increased markedly (159 msec) from the control to the easy recall condition. However, there was no increase (actually a decrease of 16 msec) from easy to hard recall conditions. An ANOVA on probe RT showed the effect of recall condition to be significant, $F(2,98) = 193$, $MS_e = 1989$, $p < .001$. Planned orthogonal comparisons showed that probe RT was shorter in the control condition than in the easy and hard conditions combined, $t\ (98) = 19.6$, $p < .001$, but probe RT in the easy recall condition was not significantly different from probe RT in the hard recall condition, $t(98) = 1.79$, $p < .10$.

Since the effects of the primary task on probe RT were confounded with the effects of practice, it is possible that the effects of practice cancelled out the effects of primary task difficulty on probe RT. In any case it is clear that the effect of the difficulty of the paired associate task on probe RT was stronger in Experiment 2 than Experiment 3. In this respect, the results of Experiments 2 and 3 are consistent with the results of Experiment 1. Both show that the visual-manual probe task was more sensitive to the demands of paired associate rehearsal than was the auditory-vocal probe task.

As in Experiments 1 and 2, the probe task interfered somewhat with recall. Analysis of recall scores showed both the effect of difficulty and the effect of the probe-no probe manipulation to be significant ($F(1,49) = 1686$, $MS_e = .006$, $p < .001$, and $F\ (1,49) = 44$, $MS_e = .002$, $p < .001$.) The interaction was also significant, $F\ (1,49) = 12.8$, $MS_e = .002$, $p < .001$, indicating that the probe task interfered more with hard than easy recall.

Individual Differences. Correlations among the RT and recall measures are shown in Table 4, with reliabilities in the diagonals. As in Experiment 2, RT in the easy recall condition was significantly correlated with recall accuracy in the hard condition, $r = -.39$, $p < .01$. However, interpretation of this correlation is complicated by the fact that control RT, which should be independent of the demands of the paired associate task, was also significantly correlated with hard recall, $r = -.37$, $p < .01$. Thus it is not possible, on the basis of the first order correlations, to say that the relationship between probe RT and hard recall is attributable to spare capacity associated with the easy paired associate task.[2] As in Experiment 2, the partial correlation between RT in the

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Insert Table 4 about here

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easy condition and recall accuracy in the hard condition was computed, removing the effects of control RT. This correlation was -.29, $p < .05$.

In summary, Experiment 2, and to a lesser extent Experiment 3, supported the validity of easy-to-hard prediction: probe RT during an easy version of a primary task predicted performance on a harder version of the same primary task. This relationship held even when control RT was partialled out. The partial correlations support the argument that the correlation is due to the fact that probe RT during the easy primary task reflects spare capacity associated with the easy task.

Experiment 4

Experiment 4 involved both the paired associate and the spatial memory primary tasks. The main purpose was to find out whether the correlational results of Experiments 2 and 3 could be extended to a spatial memory task. A second purpose was to find out whether retention of spatial information would interfere as much with response to the probe as paired associate rehearsal. Although both tasks involve short-term memory, they seem to require entirely different memorization strategies and conceivably different amounts of mental effort.

Experiment 4 was also designed to clarify interpretation of the correlational results of Experiments 2 and 3. In preceding sections, we have argued that RT to a secondary probe reflects spare capacity available during the rehearsal interval. However, we have not dealt with the question of why subjects differ in spare capacity. Suppose that the "capacity" in question is quite general, and that some subjects have more of this general capacity than others. Then individual differences in total general capacity might be important in determining the spare capacity available during rehearsal. In that case, spare capacity available during an easy version of a variety of primary tasks should predict performance on the hard version of the paired associate task. Another possibility is that differences in spare capacity are determined by the efficiency of paired associate rehearsal. For example, some subjects might adopt a strategy for rehearsal of the pairs that allowed them to maintain two pairs with a smaller expenditure of mental capacity than other subjects. In that case, we would expect the predictive power of the probe RT measure to be specific to the paired associate task. Probe RT during another primary task would probably not predict performance on the hard version of the paired associate task.

Method

Subjects

Eighty-one subjects, 52 female and 29 male, ranging in age from 18 to 60 participated in this study. They were recruited through an ad in the University newspaper, and were paid $4.50 per 1½-hour session for five sessions. The participation of some older, non-students as subjects considerably broadened the range of performance in this experiment as compared to the previous three. The effects of the age variable on performance will be reported in a separate paper. The first three sessions of the study involved a dichotic listening paradigm that will not be reported here.

Tasks

Spatial memory: Primary task. The spatial memory task is illustrated in Figure 5. At the beginning of each trial, a single plus sign was shown in the center of the screen for 1 second. Then a standard pattern appeared on the screen. In the easy version of the task, the standard pattern was formed by placing pluses in four positions randomly selected from a 3 x 3 matrix. In the hard version of the task, the standard pattern was formed by placing 10 pluses in a 7 x 7 matrix. The standard pattern remained on the screen for 3 seconds, during which time the subject was instructed to study and memorize it. After 3 seconds, the pattern was replaced by the entire matrix of pluses. This mask remained on the screen for 1 second. Finally, a test pattern was shown. The test pattern was either identical to the standard pattern or slightly different. ("Different" patterns were formed by moving one plus one space up, down, to the right or to the left.) The subject responded "same" if the test pattern was identical to the standard and "different" if it was not. "Same" responses were made with the right index finger and "different" responses with the right middle finger. There was no time pressure to respond to the test pattern.

Insert Figure 5 about here

Spatial memory: Secondary task. The secondary task in the spatial memory paradigm involved responding to an auditory probe stimulus that occurred during the 3-second study phase of the primary task. The probe was a 100-msec tone. Whereas probes in the previous experiments continued until the subject responded, in this experiment they were terminated automatically after 100 msec. Probes occurred equally often 500, 1000, or 1500 msec after the onset of the standard pattern. During each 32-trial block, there were eight probes at each interval and eight catch trials during which no probes occurred. The subject pressed a key with the left index finger as quickly as possible when a probe occurred.

Paired associate: Primary task. The easy version of this task was exactly the same as that used in Experiments 2 and 3; subjects kept track of two letter-digit pairs. In the hard version subjects kept track of five pairs.

Paired associates: Secondary task. The secondary probe task was identical to that used in Experiments 2 and 3 except that the probe was a 100-msec tone. Probes occurred equally often 500, 1000, or 1500 msec after the onset of a new letter-digit pair. In each 32-trial block, eight probes occurred at each interval, and there were eight catch trials on which no probe occurred.

Procedure

Day 4 of the study was devoted to the spatial memory task, and Day 5 to the paired associate task. There were five conditions for each of the two tasks.

Secondary control. Subjects responded only to the probe tones. Stimuli for the primary task were presented, but subjects did not respond to them.

Easy primary-no probes. The easy primary task was presented alone.

No probe occurred.

Easy primary with probes. The easy version of the primary task was combined with the secondary probe RT task.

Hard primary-no probes. The hard primary task was presented alone. No probes occurred.

Hard primary with probes. The hard version of the primary task was combined with the secondary probe RT task.

On each of the two days, there were 10 blocks of 32 trials each, two blocks for each of the five conditions listed above. In the first five blocks, the conditions were presented in the order listed above, and in the last five blocks, this order was reversed.

Results and Discussion

Group Results

Seven measures were computed for each subject on each task: Mean probe RT in the control, easy primary, and hard primary conditions, and proportion of correct responses to the primary task in the easy condition alone, easy condition with probes, hard condition alone and hard condition with probes. These measures were summed across the two blocks of each condition. Mean probe RT is shown in Figure 6, and mean proportion of correct responses is shown in Figure 7.

Insert Figures 6 and 7 about here

Probe RT was analyzed using a repeated measures ANOVA in which the factors were primary task type (paired associate or spatial memory) and primary task difficulty (control, easy primary, or hard primary). The main effect of primary task type was significant ($F(1,80) = 227$, $MS_e = 14702$, $p < .001$) indicating that RT to the probe was longer during the paired associate than the spatial memory primary task. The main effect of primary task difficulty was also significant ($F(2,160) = 279$,

MS_e = 10119, $p < .001$, as was the interaction ($F(2,160) = 121$, MS_e = 6414, $p < .001$). RT increased with the demands of the primary tasks, and this effect was stronger during the paired associate than the spatial memory task.

Probe RTs were also analyzed separately for each of the primary tasks. For the spatial memory task, the effect of primary task difficulty was significant, $F(2,160) = 92$, MS_e = 3554, $p < .001$. Planned orthogonal comparisons on spatial memory RTs showed that RT was shorter in the control condition than in the easy and hard conditions combined, $t(160) = 13.0$, $p < .001$, and RT was shorter in the easy recall condition than in the hard recall condition, $t(160) = 4.12$, $p < .001$. For the paired associate task, the effect of primary task difficulty was also significant, $F(2,160) = 252$, MS_e = 12,979, $p < .001$. Again, planned orthogonal comparisons showed that RT was shorter in the control condition than in the easy and hard conditions combined, $t(160) = 22.2$, $p < .001$, and RT was shorter in the easy recall condition than in the hard recall condition, $t(160) = 3.15$, $p < .01$.

In Experiments 1, 2, and 3, where probes were terminated by the subject's response, less than 1% of the probes were ignored. In Experiment 4, where the duration of the probe was 100 msec regardless of the subject's response, many more probes were ignored. For the spatial memory primary task, 2% of the probes were ignored in the control condition, 2% during the easy primary, and 3% during the hard primary. For the paired associate primary task, 1% of the probes were ignored in the control condition, 8% during the easy primary, and 12% during the hard primary. Thus the data on ignored probes are consistent with the RT data in showing that the paired associate task interfered more with response to the probes than did the spatial memory task.

Accuracy of responses to the primary task also indicated that there was more interference between the probe task and the paired associate task than between the probe task and the spatial memory task. Accuracy scores from the two primary tasks were analyzed separately, since they were not directly comparable. (Chance performance in the spatial memory task was .50, while chance performance in the paired associate task was .125.) In each case, a repeated measures ANOVA was performed in which the two factors were difficulty of the primary task (easy or hard) and probe condition (probes or no probes). For the spatial memory task, only the main effect of difficulty was significant, $\underline{F}(1,80) = 1513$, $MS_e = .003$, $p < .001$. Neither the main effect of probe condition nor the interaction was significant. Probes did not interfere with accuracy of responses to the spatial memory task. In the analysis of paired associate recall, both the main effect of difficulty ($\underline{F}(1,80) = 214$, $MS_e = .020$, $p < .001$) and the main effect of probe condition ($\underline{F}(1,80) = 48$, $MS_e = .005$, $p < .001$) were significant. The interaction was only marginally significant, $\underline{F}(1,80) = 3.6$, $MS_e = .005$, $p < .10$. In the case of the paired associate task, the probes did interfere with the accuracy of recall, and this effect was slightly greater for the hard than the easy version.

The paired associate data from Experiment 4 replicate those of the previous experiments. Paired associate rehearsal caused a significant delay in responding to the probes, and the probes also caused some decrement in accuracy of recall. Memorization of the spatial patterns caused much less of a delay in responding to the probes, and accuracy of response to the spatial patterns was uneffected by the probes. The most obvious interpretation of the fact that there was less interference between the spatial memory and the probe tasks is that subjects devoted less effort to studying the spatial patterns than to rehearsing the paired associates.

Why should this be the case? Perhaps it was because an active verbal strategy can be employed to maintain the paired associates, but no similar strategy is available for the spatial memory task. Subjects can improve their performance on the paired associate task by devoting more mental resources to rehearsal. There is no similar method of utilizing mental resources to improve performance on the spatial memory task. This explanation is consistent with introspection concerning the two tasks. Subjects spoke of being exhausted by the hard paired associate task. But they reported that a passive attitude was more effective in memorizing the spatial patterns.

Individual Differences

Table 5 shows the correlation matrix of measures from both spatial memory and paired associate tasks. Split-half reliabilities are shown in the diagonal.

Insert Table 5 about here

For the spatial memory task, there was a significant correlation between probe RT in the easy condition and proportion correct on the hard version of the primary task, $r = -.29$, $p < .01$. However, the correlation between control RT and proportion correct on the hard primary task was almost as great, $r = -.27$, $p < .05$. The partial correlation between proportion correct in the hard condition and probe RT in the easy condition, removing the effects of control RT, was only $-.14$, $p > .10$. Thus when the effects of control RT were removed, the easy-to-hard prediction was not supported in the spatial memory data.[3]

The data from the paired associate task replicated the results of Experiments 2 and 3. The correlation between probe RT during easy recall and accuracy of hard recall was $-.49$, $p < .01$, while the correlation between control RT and accuracy in hard recall was only $-.21$, $p < .10$. The partial correlation between accuracy in the hard condition and probe RT in the easy condition, removing the effects of control RT, was .47, $p < .01$. For the paired associate task, the easy-to-hard prediction was confirmed.

Why was the easy-to-hard correlation insignificant in the case of the spatial memory task? The answer may be related to the resource requirements of that task. We suggested earlier that subjects use a resource-demanding rehearsal strategy to memorize paired associates, but that no such strategy is available for the spatial memory task. For this reason, resource limitations may determine an individual's performance on the paired associate task, but not on the spatial memory task. If availability of resources is not the determining factor in the spatial task, then one would not expect a relationship between spare capacity available during the easy version of the task and performance on the harder version.

This argument is related to Norman and Bobrow's distinction between resource-limited and data-limited processes. An individual's performance on the paired-associate task may be resource-limited, in the sense that performance is determined by the amount of resources available to that individual. If more resources were available, performance would improve. But performance on the spatial memory task may be data-limited; i.e. an increase in available resources would not improve performance. Some more specific factor, such as the duration of the visual image, may determine an individual's performance on the spatial memory task.

This experiment was designed to look into one further question concerning the easy-to-hard prediction. Would the spare capacity measure associated with one task predict performance on the other? If individual differences in spare capacity reflect differences in total capacity, then we might expect spare capacity available during the spatial memory task to predict performance on the paired associate task. But if individual differences in spare capacity reflect differences in the efficiency with which different subjects carry out a particular task, then we would not expect the easy-to-hard correlation to be significant across tasks.

In fact, the correlation between probe RT during the easy spatial memory task and accuracy on the hard paired associate task was significant ($\underline{r}$ = -.29, $p < .01$), but not as high as the easy-to-hard correlation within the paired associate task. When control RT for the spatial memory task was partialled out, the correlation was reduced to -.23, $p < .05$. This leaves unresolved the question of whether the easy-to-hard correlation is due to individual differences in total capacity or to differences in the efficiency of paired associate rehearsal. Both factors may be important.

As might be expected, spare capacity associated with the paired associate task failed to predict performance on the hard spatial memory task. The partial correlation between RT during the easy paired associate task and accuracy on the hard spatial memory task, holding control RT constant, was only -.08, $p > .10$. This finding is consistent with the idea that performance on the hard spatial memory task is determined by some factor other than total available resources.

General Discussion

The experiments reported here were conceived within the framework of a very simple theory of attention. According to this theory, a) each subject has a limited supply of general mental resources; b) primary and secondary tasks compete for these resources; c) the subject controls allotment of resources so that the primary task is given priority over the secondary task; d) performance of the secondary task improves as more resources are alloted to it; and e) the resource demands of the primary task increase as that task is made more difficult. The prediction most commonly associated with such a theory is that performance on the secondary task will decrease as the difficulty of the primary task is increased. We have argued that the theory entails another prediction: The secondary task should provide a measure of individual differences in spare capacity associated with an easy version of the primary task, and this measure should be positively correlated with performance on a harder version of the same primary task. We have called this the "easy-to-hard" correlation.

The group results from these experiments were consistent with the first prediction: that secondary task performance should decrease as the demands of the primary task increase. In every case, performance on the secondary task decreased markedly from the control to the dual-task condition, and, with the exception of Experiment 3, secondary task performance decreased as the difficulty of the primary task was increased. The easy-to-hard prediction was supported for the paired associate primary task (Experiments 2, 3, and 4), but not for the spatial memory primary task (Experiment 4).

The fact that spare capacity during the easy version of the paired associate task predicted performance on the harder version of that task has at least two interpretations. One could argue that subjects with more spare capacity during the easy version of the paired associate task had more total capacity to begin with. Alternatively, one could argue that subjects with more spare capacity during the easy paired associate task performed that task more efficiently; i.e. with a smaller output of mental resources. If the former argument were true, then we would expect spare capacity associated with any capacity demanding task to predict performance on the difficult paired associate task. It was not possible to eliminate the first alternative on the basis of these experiments. However, it seems quite likely that the easy-to-hard correlation was due, at least in part, to individual differences in efficiency of paired associate rehearsal. Those subjects who performed the easy paired associate task more efficiently had more capacity to spare for the secondary task. Those subjects also achieved high scores on the more difficult version of the paired associate task.

A necessary precondition for the success of the easy-to-hard prediction is that performance on the difficult primary task be limited by the availability of resources. In the case of the paired associate task, we have suggested that subjects who achieved higher scores did so by utilizing a limited supply of resources more efficiently. The group data from the spatial memory task indicated that the spatial task also demanded mental resources, since RT to the probe increased from the control to the easy condition and from the easy to the hard condition. However, RT to the probe during the hard version of the spatial memory task was considerably faster than RT to the probe during the hard version of the paired associate task. Faster RTs during the hard spatial memory task suggest that subjects devoted less than total capacity to that task, even though performance was far from ceiling. Thus individual performance on the task may have been limited not by the availability of resources, but by some other factor. This may explain why the easy-to-hard prediction was unsuccessful in the case of the spatial memory task.

Verbal rehearsal strategies provide a means by which subjects can use mental resources to increase recall scores on the paired associate task.

No such rehearsal strategy was useful in maintaining the visual patterns of the spatial memory task. The fact that the spatial memory task did not lend itself to an active, resource-demanding rehearsal strategy may explain why subjects devoted less than full capacity to it.

Even in the paired associate data, the easy-to-hard correlations were only modest. The reason may be the nature of the secondary task measure. The rationale for the easy-to-hard prediction involves the assumption that secondary task performance provides a measure of spare capacity associated with the primary task. In fact, several other factors influence performance on the secondary task. One of these is individual variation in performance on the secondary task alone. We have attempted to control this factor by statistically removing the effects of control RT. Other factors cannot be controlled in this way because they cannot be measured. For example, secondary task performance may reflect the resource demands of coordinating primary and secondary tasks, as well as the demands of the primary task itself. Secondary performance may also reflect individual differences in the priorities subjects assign to the two tasks, or in overall motivation. All these factors make secondary task performance a somewhat impure measure of spare capacity, and may serve to attenuate the easy-to-hard correlation.

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Footnotes

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2. An interesting side question is why vocal RT to an auditory stimulus should be correlated with recall, when manual RT to a visual stimulus was not. Baddeley's assertion that an individual's immediate memory span is determined by the speed with which the person can pronounce the items to be recalled provides a possible link (Baddeley, Thompson, & Buchanan, 1975). It is tempting to speculate that the speed of vocal response is related to the speed of rehearsing a series of words or numbers, which, in turn, determines recall accuracy in the paired associate task.

3. A problem arises in interpreting correlations involving proportion of correct responses in the hard spatial memory task, since the reliability of that measure was only .59. In order to increase the reliability, proportion correct in the probe and no-probe conditions were combined. This seemed justified since probes had no effect on mean accuracy scores for the spatial task, and because the patterns of correlations involving accuracy in probe and no-probe conditions were very similar. The reliability of the new measure was .73. The correlation between the combined accuracy measure and RT during the easy spatial memory task was -.32, $p<.01$, but

the correlation with control RT was -.33, $p<.01$. The partial correlation between the combined accuracy measure and RT during the easy version, removing the effects of control RT, was 0.12, $p>.10$. Thus the failure of the easy-to-hard correlation in the case of the spatial memory task can probably not be attributed to the unreliability of the accuracy measure.

Table 1

Sequence of Events for the Two-Item Memory Load, Experiment 1

Event	Display	Duration
Sequential presentation of initial pairs.	A = 7 B = 3	3 sec 3 sec
Question. The correct answer is 3.	B = ?	Subject paced.
Rehearsal interval. Letter just queried is paired with a new number.	B = 4	3 sec
Probe. A probe may occur 500, 1000, or 1500 msec after presentation of a new pair.	(****) B = 4	Probe is presented until subject responds for a maximum of 1500 msec.
Question. The correct answer is 7.	A = ?	Question remains on screen until subject responds.
Rehearsal interval. Letter just queried is paired with a new number.	A = 5	3 sec

Table 2

Order of Conditions in Experiments 2 and 3

	Block				
	1	2	3	4	5
Day 1	RT Control	Easy Recall No Probes	Easy Recall with Probes	Hard Recall No Probes	Hard Recall with Probes
Day 2	RT Control	Easy Recall with Probes	Easy Recall No Probes	Hard Recall with Probes	Hard Recall No Probes

Table 3

Correlation Matrix, Experiment 2

	1	2	3	4	5	6	7
1. Probe RT Control Condition	.76						
2. Probe RT Easy Recall Condition	.52	.90					
3. Probe RT Hard Recall Condition	.36	.75	.94				
4. Proportion Correct Easy Recall without Probes	-.09	-.27	.01	.63			
5. Proportion Correct Easy Recall with Probes	-.04	-.44	-.14	.67	.80		
6. Proportion Correct Hard Recall without Probes	-.05	-.40	.07	.52	.59	.74	
7. Proportion Correct Hard Recall with Probes	-.03	-.37	.06	.44	.61	.85	.83

Note. With 48 subjects, correlations of .28 and .36 are significant at the .05 and .01 levels, two-tailed.

Table 4

Correlation Matrix, Experiment 3

	1	2	3	4	5	6	7
1. Probe RT Control Condition	.84						
2. Probe RT Easy Recall Condition	.40	.84					
3. Probe RT Hard Recall Condition	.37	.60	.77				
4. Proportion Correct Easy Recall without Probes	-.13	-.12	-.08	.60			
5. Proportion Correct Easy Recall with Probes	-.15	-.19	-.07	.80	.72		
6. Proportion Correct Hard Recall without Probes	-.37	-.39	-.16	.28	.25	.63	
7. Proportion Correct Hard Recall with Probes	-.22	-.20	.18	.40	.32	.59	.46

Note. With 50 subjects, correlations of .27 and .35 are significant at the .05 and .01 levels, two-tailed.

Table 5

Correlation Matrix, Experiment 4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Spatial Memory Task														
1. Probe RT Control Condition	_.99_													
2. Probe RT Easy Primary Condition	.76	_.99_												
3. Probe RT Hard Primary Condition	.70	.88	_.97_											
4. Proportion Correct Easy Primary without Probe	-.31	-.31	-.18	_.55_										
5. Proportion Correct Easy Primary with Probe	-.49	-.46	-.33	.61	_.61_									
6. Proportion Correct Hard Primary without Probe	-.27	-.29	-.13	.27	.40	_.59_								
7. Proportion Correct Hard Primary with Probe	-.30	-.26	-.18	.41	.47	.48	_.50_							
Paired Associate Task														
8. Probe RT Control Condition	.82	.69	.63	-.20	-.33	-.34	-.31	_.99_						
9. Probe RT Easy Recall Condition	.52	.63	.55	-.27	-.35	-.27	-.21	.61	_.97_					
10. Probe RT Hard Recall Condition	.41	.56	.52	-.03	-.21	-.27	-.11	.49	.65	_.96_				
11. Proportion Correct Easy Recall without Probe	-.38	-.53	-.40	.57	.41	.38	.29	-.39	-.48	-.11	_.93_			
12. Proportion Correct Easy Recall with Probe	-.20	-.39	-.27	.46	.38	.47	.50	-.28	-.41	-.04	.68	_.96_		
13. Proportion Correct Hard Recall without Probe	-.19	-.29	-.20	.40	.28	.27	.39	-.21	-.49	-.06	.57	.73	_.96_	
14. Proportion Correct Hard Recall with Probe	-.24	-.29	-.18	.44	.29	.30	.47	-.26	-.41	-.04	.55	.69	.89	_.95_

Note. With 41 subjects, correlations of [illegible] and [illegible] are significant at the .05 and .01 levels, two-tailed.

Figure Captions

Figure 1. Mean probe RT for the visual-manual and auditory-vocal secondary tasks as a function of memory load in the primary task, Experiment 1.

Figure 2. Proportion of items correctly recalled in the control and dual-task conditions as a function of memory load, Experiment 1.

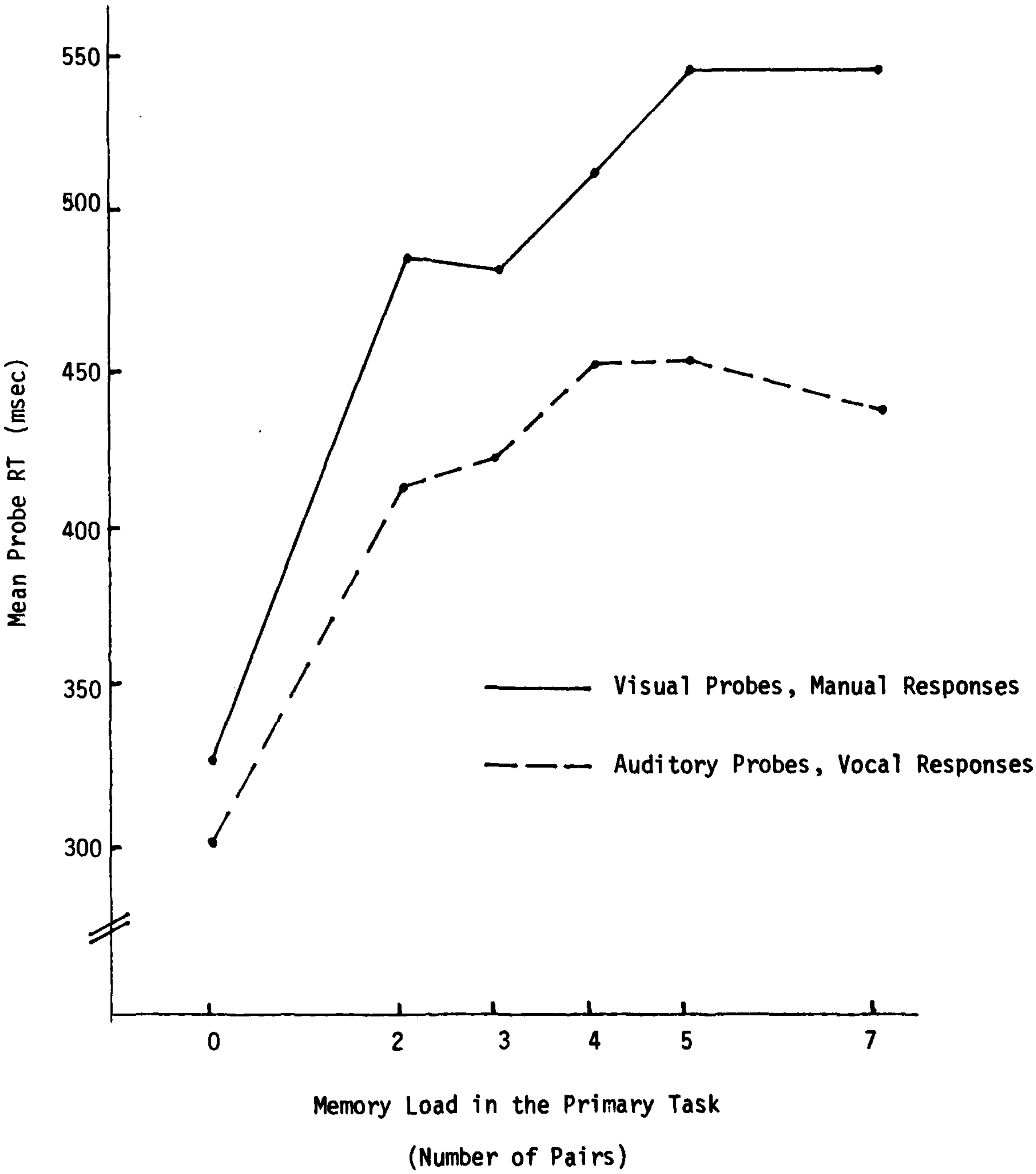
Figure 3. Mean probe RT as a function of memory load in the primary task in Experiment 2 (visual-manual probe task) and Experiment 3 (auditory-vocal probe task).

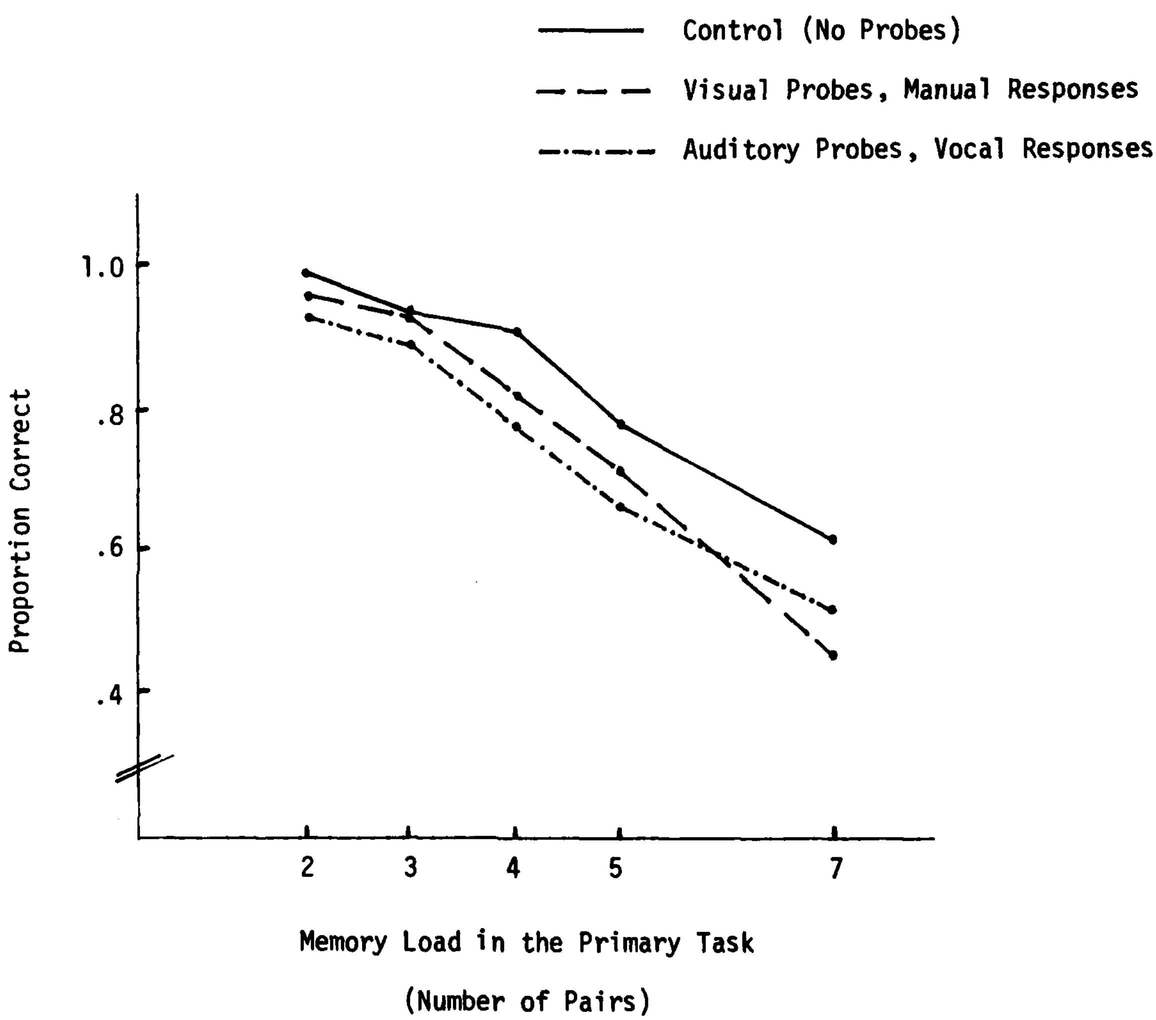
Figure 4. Proportion of items correctly recalled in the easy and hard versions of the primary task as a function of probe condition, Experiments 2 and 3.

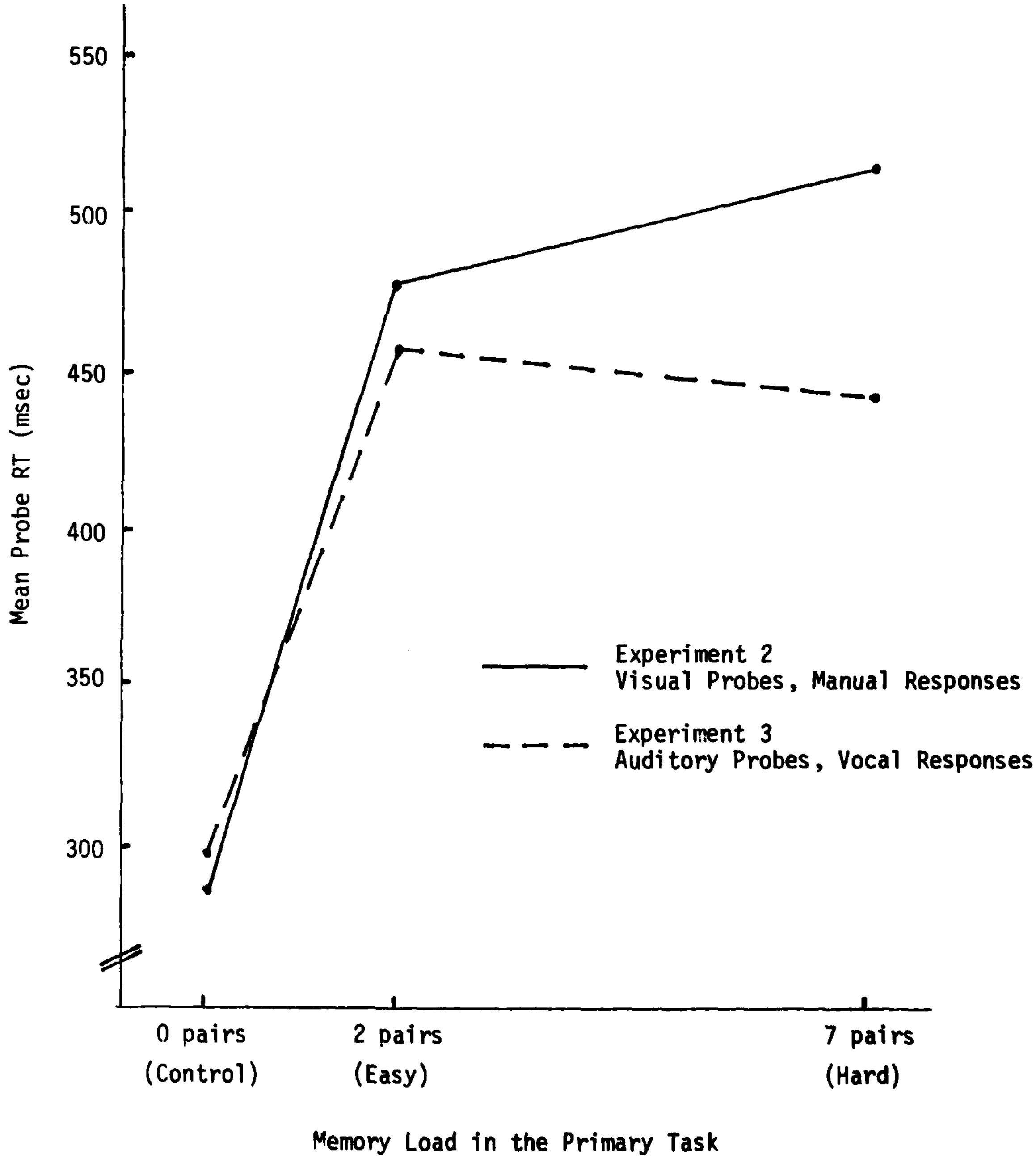
Figure 5. Sequence of events in the spatial memory task of Experiment 4.

Figure 6. Mean probe RT during paired associate and spatial memory primary tasks as a function of primary task difficulty, Experiment 4.

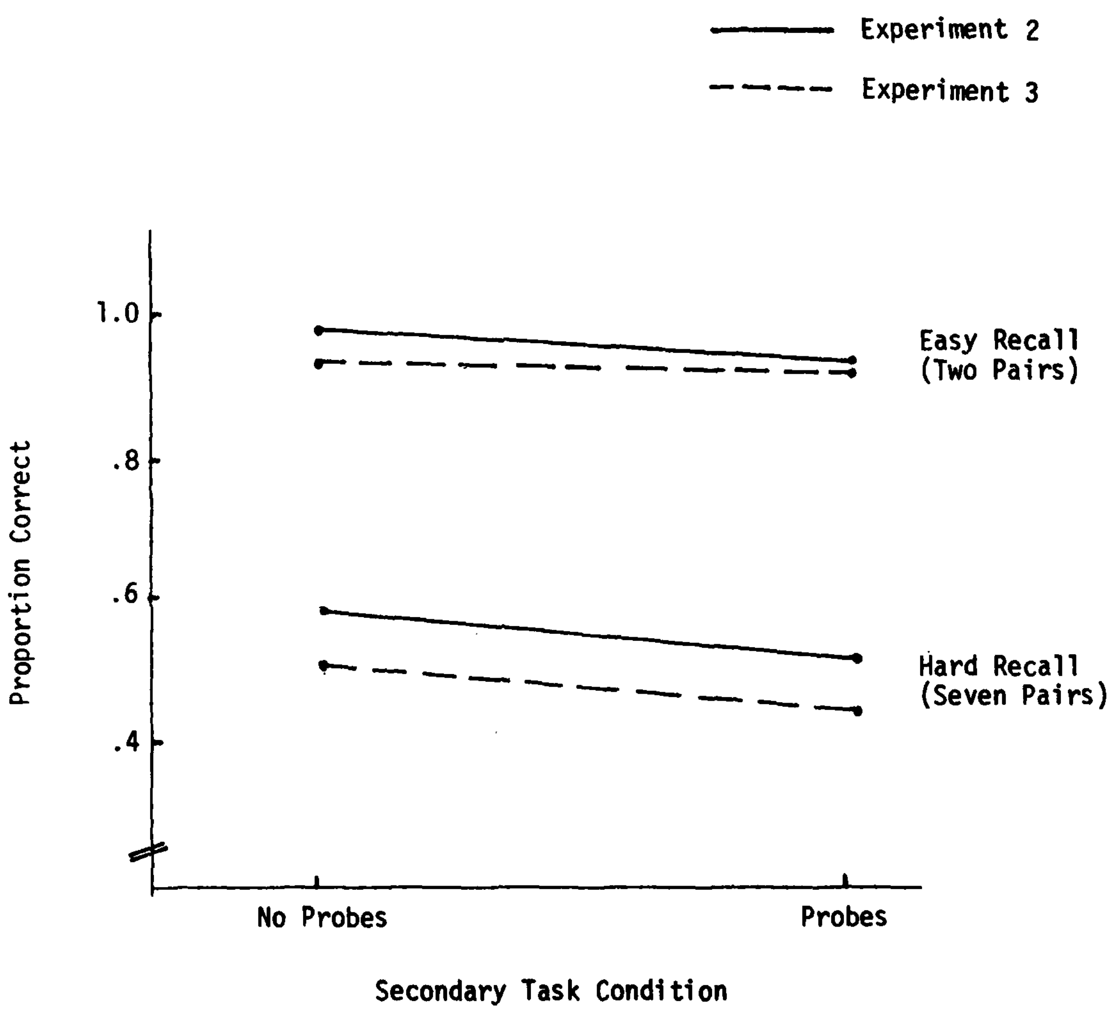
Figure 7. Proportion of correct responses to the two primary tasks as a function of probe condition, Experiment 4.


550
500
450
400
350
300
Mean Probe RT (msec)
Visual Probes, Manual Responses
Auditory Probes, Vocal Responses
0
2
3
4
5
7
Memory Load in the Primary Task
(Number of Pairs)

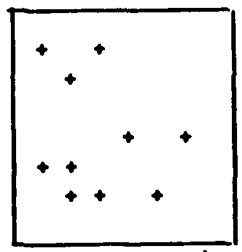
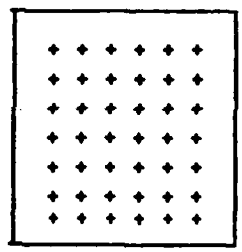
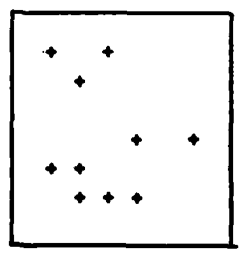

Control (No Probes)
Visual Probes, Manual Responses
Auditory Probes, Vocal Responses
1.0
.8
.6
.4
Proportion Correct
2
3
4
5
7
Memory Load in the Primary Task
(Number of Pairs)

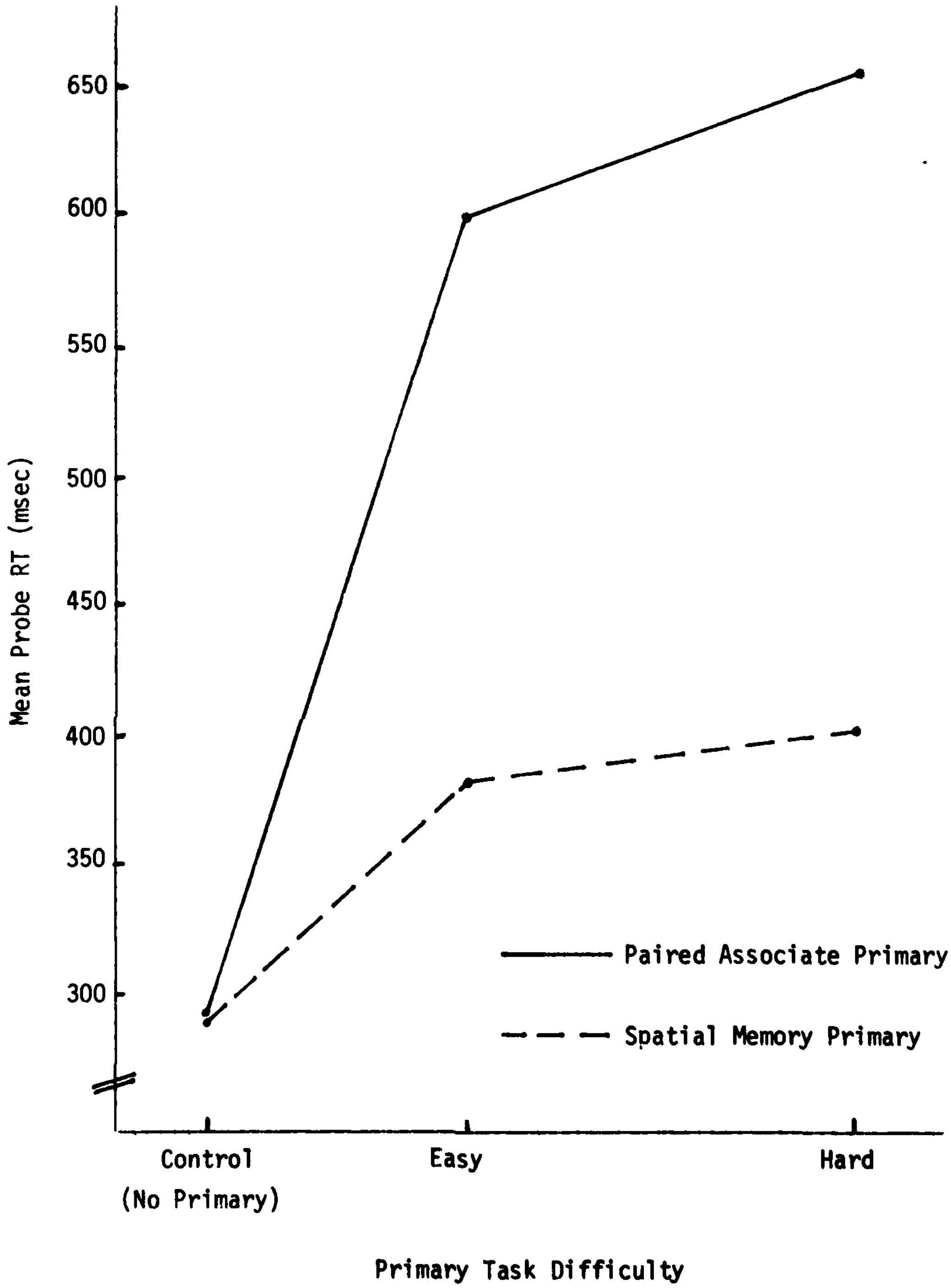


Mean Probe RT (msec)
550
500
450
400
350
300
Experiment 2
Visual Probes, Manual Responses
Experiment 3
Auditory Probes, Vocal Responses
0 pairs
(Control)
2 pairs
(Easy)
7 pairs
(Hard)
Memory Load in the Primary Task

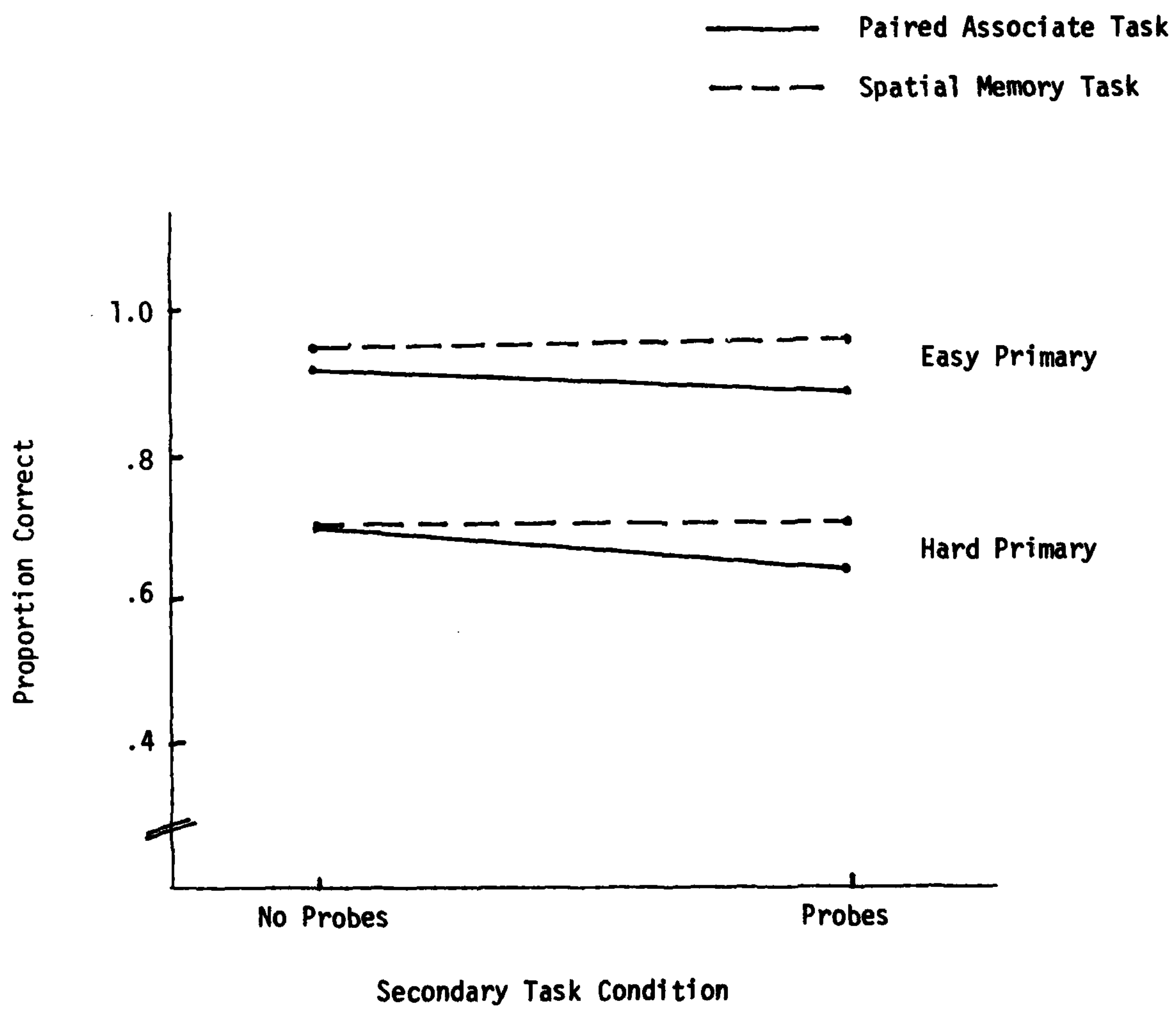


Experiment 2
Experiment 3
1.0
.8
.6
.4
Proportion Correct
Easy Recall
(Two Pairs)
Hard Recall
(Seven Pairs)
No Probes
Probes
Secondary Task Condition

Event	Display	Duration
Standard pattern. (Probe could occur 500, 1000, or 1500 msec after onset of standard pattern.		3 sec
Mask.		1 sec
Test pattern. Subject responds as to whether test pattern is the same or different from the standard.		Test pattern remains on screen until the subject responds.



650
600
550
500
450
400
350
300
Mean Probe RT (msec)
Paired Associate Primary
Spatial Memory Primary
Control
(No Primary)
Easy
Hard
Primary Task Difficulty


Paired Associate Task
Spatial Memory Task
1.0
.8
.6
.4
Proportion Correct
Easy Primary
Hard Primary
No Probes
Probes
Secondary Task Condition

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