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STIMULUS CONTROL EXERTED BY REMEMBER CUES OVER PROCESSING IN PIGEONS' SHORT-TERM MEMORY

by

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To Raquel and Francisco

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ABSTRACT

The aim of the present research was to provide further evidence regarding the role of remember cues on pigeon short-term memory. The first two experiments were conducted to determine whether, using a single cuing procedure, control over delayed matching-to-sample (DMTS) performance could be demonstrated by establishing a no cue condition as an implicit cue to forget. In Experiment 1, subjects were provided with training in a procedure where both forget cue (F) and no cues indicated the omission of the comparison stimuli at the end of the delay interval. In Experiment 2, naive subjects were trained with remember (R) and F trials cued from the outset. In both experiments the cuing effect was evaluated during R, F, and no cue probe trials where the cues were presented in the beginning, middle, or end of a 3 sec delay interval. The results revealed that DMTS accuracy on F cued probe trials was significantly lower than that on R cued or no cue probe trials. Performance on R cued and no cue probe trials was statistically equivalent despite both the explicit training of the no cue condition to function as an implicit cue to forget (Experiment 1), and cuing R and F trials from the outset and presenting the no cue trials only during probe testing (Experiment 2). The main aim of the third experiment was to determine whether the attenuating effect of an R cue over a previously presented F cue was the result of conditioning history. The cuing effect was evaluated in three types of single cued trials (R, F, and no cue), and two types of double cued trials (forget-remember, FR, and forget-novel, FN). The results indicated identical performance in FR and FN cued probe trials, suggesting that the novelty of presenting two cues in the retention interval may play a role in determining DMTS performance in double cued probe trials. Performance on double cued and no cue probe trials did not significantly differ from R or F cued probe trials. The evidence is contrary to the hypothesis that, as a result of previous training, a no cue functions as an implicit remember cue.

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INTRODUCTION

A number of studies have investigated the stimulus control of short-term forgetting using human subjects with a paradigm called directed forgetting (Burwitz, 1974; Epstein, 1972; Horton & Petruk, 1980; Jongeward, Woodward, & Bjork, 1975). Typically, in a directed forgetting experiment some of the items are followed by a signal to remember (R cue) and others by a signal to forget (F cue). The R cue indicates to the subjects which items will be tested subsequently, while an F cue indicates which items will not be tested. Despite these cues, some F cued items may be tested during probe trials. The higher retention of R cued items than F cued items is the so-called directed forgetting effect (Bjork, 1972).

In spite of the experiments exploring the directed forgetting phenomenon with human subjects, very few attempts have been made to obtain comparable demonstrations of stimulus control of forgetting with other species. However, several researchers of animal memory have suggested that animals have the same capacity to control memory processing and they have included accounts similar to directed forgetting in their explanation of memory process in animals. Both Olton (1978) and Honig (1978) suggested that animals form a working memory to solve discrimination problems. A working memory is established when different stimuli govern the required response on different trials so that the information that the subject must remember varies from trial to trial (Honig, 1978). The information in a working memory directs subsequent behaviour in a particular trial. Olton (1978) proposed that to solve a spatial discrimination problem, rats maintained the information in working memory for as long as needed to solve the problem, and then "reset" it. Similarly, Honig (1978) pointed out that pigeons convert the information in the stimulus into an instruction to perform the criterion response and the instruction is maintained until the response is executed. The "resetting" mechanism or the termination of the instruction makes choice behaviour in subsequent tests more accurate by eliminating from the working memory irrelevant information from previous trials. If these assumptions are correct, it should be possible to establish stimulus control over forgetting and remembering in a way similar to that demonstrated with humans.

In studying animal short-term memory, the delayed matching to sample (DMTS) paradigm has been frequently employed (Carter & Werner, 1978; Cumming & Berryman, 1965; Grant, 1981; Grant & Roberts, 1976; Maki, 1979; Maki & Hegvik, 1980; Roberts & Grant, 1976). Typically the DMTS task begins with the presentation of a sample stimulus for a specified interval or until the response requirement is satisfied. Then, after a delay interval, the comparison stimuli occur. A response to a comparison is reinforced if the selected stimulus is identical to the sample. Matching accuracy is measured by percent of correct responses, if the comparison stimuli are presented simultaneously on the side keys, or by a discrimination index, if the comparison stimuli are presented successively on the same key. A discrimination index is obtained by dividing the total number of responses to the matching comparison stimuli by the total number of responses to both matching and non-matching stimuli and then multiplying this result by 100. Accuracy in a DMTS task is taken as a measure of sample retention because the sample is absent when the response is made to the comparison stimuli (Maki & Hegvik, 1980).

Recent modifications to the DMTS procedure permit the study of stimulus control of forgetting in animal short-term memory. The DMTS procedure to study directed forgetting involves the use of signals or cues indicating whether the sample will or will not be tested subsequently. The effect of these signals is evaluated by testing retention of all samples during probe trials.

In animal research, presample and postsample cuing procedures have been used to signal the presence or the absence of a memory test. If the cue is presented prior to the sample stimulus (Stonebraker & Rilling, 1981), or if the sample itself is the signal (Maki, 1979; Maki, Gillund, Hauge, & Siders, 1977), then it is termed presample cuing. It is called postsample cuing if the signal follows the sample presentation (Grant, 1981; Maki & Hegvik, 1980; Rilling, Kendrick, & Stonebraker, in press; Stonebraker & Rilling, 1981; Stonebraker, Rilling, & Kendrick, 1981).

Another procedural variation in the study of directed forgetting has been the use of single or double cuing. If only one cue, forget or remember, occurs in a trial, it is termed single cuing. Double cuing refers to the occurrence of two cues in the same trial. In both animal and human research, single cuing has been frequently used to demonstrate the stimulus control of R and F cues over short-term memory processes, and to investigate the possible effects of the cue's temporal position within the retention interval (Grant, 1981; Stonebraker & Rilling, 1981; Timmins, 1974). Double cuing procedures have been employed to investigate both whether the level of processing can be restored to precue levels by presenting an R cue after an F cue as well as whether the directed forgetting effect is obtained when an F cue occurs after an R cue (Grant, 1981; Stonebraker et al., 1981).

LITERATURE REVIEW

This review does not attempt to cover all the possible topics of interest in directed forgetting. The goal is to provide a reasonable view of the current state of directed forgetting research as well as the theoretical interpretations given to the phenomenon. This review begins with a general description of the procedural aspects involved in the demonstration of control by F cues on DMTS performance. It continues with a description of the experiments in which the temporal parameters of F cues have been manipulated and the experiments with postsample double cuing procedures. The review finishes with a description of the principal theoretical interpretations of the directed forgetting phenomenon and the role of R cues on directed forgetting.

I. PROCEDURAL ASPECTS INVOLVED IN THE DEMONSTRATION OF CONTROL BY F CUES OVER DMTS PERFORMANCE.

Several researchers have demonstrated that, in both choice and successive DMTS tasks, matching accuracy on F cued probe trials is inferior to matching accuracy on R cued probe trials (Grant, 1981; Maki & Hegvik, 1980; Stonebraker & Rilling, 1981; Stonebraker et al., 1981). With animals as experimental subjects, Maki and Hegvik (1980, Experiment 1) were the first to report that the presence of a postsample F cue reduced matching accuracy. Pigeons were trained in a choice DMTS task. The presentation of food for 2 sec (food sample) or a 2 sec blackout (no food sample) served as a sample stimulus. If the trial started with a food sample, then when the comparison stimuli were presented, the correct comparison stimulus was red. If the trial started with no food sample, then the correct comparison stimulus was green. Two types of cues signalled how the trial would terminate. The R cue signalled that the usual comparison stimuli would be presented after the retention interval. The F cue signalled the omission of the comparison stimuli at the end of the trial. For three of the birds, the R cue was a brief period of illumination of the houselight and the F cue was darkness (group dark). For the other three birds, the function of the cues was reversed (group light). Long (6-15 sec) and short (3 sec) delay intervals were used. Each session consisted of 64 trials divided into 8 randomized blocks. The effect of the cues was evaluated in probe trials containing the usual comparison stimuli, regardless of the previous cue. During testing, the last block of trials (8 trials) on every other session contained only probe trials.

Maki and Hegvik's results indicated that the directed forgetting effect tended to be complexly dependent on identity of the F cue, length of the delay interval, and type of sample. If the sample was no food and the F cue was darkness, the directed forgetting effect was not reliable. That is, following R cues, performance was uniformly accurate and independent of other variables; in contrast, matching accuracy was much less when the F cue was illumination than when it was darkness. The directed forgetting effect was reliable with long delays but unreliable with short delays.

Based on these results, it is not clear whether the directed forgetting effect was the result of the omission of the comparison stimuli, or the lack of an opportunity to perform choice responses and obtain reinforcement. In other words, F cued and R cued trials varied along two dimensions.

First, on R cued trials, the subject must remember the sample stimulus to match correctly, while on F cued trials, a memory for the sample is irrelevant since it will not be tested subsequently. Second, R cued trials ended with an opportunity to perform choice responses and the presentation of reinforcement on matching trials whereas F cued trials never terminated with the execution of choice responses or reinforcement.

Maki and Hegvik (1980, Experiment 2) devised a comparison-substitution procedure to determine whether the decline in performance on F cued probe trials was the result of the irrelevance the sample stimulus or the lack of an opportunity to perform choice responses and the absence of reinforcement at the end of the trial. In the comparison-substitution procedure, an unconditional discrimination was presented instead of the comparison stimuli following F cues. Six pigeons were trained in a choice DMTS task with food and no food as sample stimuli. Brief periods of houselight illumination and darkness during the retention interval were used as postsample cues. For four birds, the R cue was houselight illumination and the F cue was darkness (group dark). For the other two birds, the function of the cues was reversed (group light). During the comparison-substitution training, R cued trials terminated with the comparison stimuli presentation and reinforcement for correct choices. Forget cued trials ended with the presentation of a vertical and a horizontal line on the comparison keys. A single peck to the vertical line was always followed by reinforcement. During the comparison-omission training, F cued trials terminated with the omission of the comparison stimuli whereas R cued trials terminated with the usual comparison stimuli. Long (5-9 sec) and short (2 sec) retention intervals were used. The cuing effects were evaluated in probe trials containing the usual comparison stimuli at the end of the trial. Maki and Hegvik hypothesized that, if the opportunity to perform choice responses and obtain reinforcement were important, F cues should not be effective in decreasing performance during the comparison-substitution task. Alternatively, if the F cues decrease matching accuracy because they signal the irrelevance of the sample stimulus, then comparison-omission and comparison-substitution should produce an equivalent decrement in matching accuracy.

Maki and Hegvik indicated that different results were obtained depending on whether the sample stimulus was food or no food. If the sample was no food and the F cue illumination then, performance on F cued trials was significantly lower than that on R cued trials, regardless of treatment (comparison-omission or comparison-substitution) or length of the retention interval (short or long). In contrast, if the sample was food, and the retention interval was long, matching was less accurate during F cued probe trials than during R cued probe trials, and performance tended to be worse during comparison-omission than during comparison-substitution. Matching performance after a short retention interval was not affected by cuing (forget or remember), treatment (comparison-omission or comparison-substitution), or groups (dark or light). Matching accuracy following R cues after long delays did not differ between comparison-omission and comparison-substitution.

Maki and Hegvik concluded that "comparison-omission per se may not be responsible for the effectiveness of an F cue. Instead, either the lack of an opportunity to choose among simultaneously presented stimuli or the lack of an opportunity for reinforcement seems to be critical" (p. 573). However, Maki and Hegvik's results are difficult to interpret. Several problems must be taken into account in evaluating these findings: (1) previous research has shown that illumination, one of the cues employed in Maki and

Hegvik's experiment, is a powerful event in disrupting matching performance (Grant & Roberts, 1976; Roberts & Grant, 1978). Additional support to the notion that illumination has a disruptive effect is provided by the fact that during baseline training the houselight significantly reduced DMTS accuracy; (2) the interactions found were complex and difficult to interpret (e.g., the directed forgetting effect varied as a function of type of sample, identity of the cue, length of the delay), and it may be possible that some of these interactions were the result of the disruption on performance produced by the illumination presented in the retention interval; (3) the use of food and no food as sample stimuli. It is uncertain whether the comparison between food and no food samples is legitimate. Thus, food presentation is confined to the feeder and it is always linked to a very specific consumatory response, eating. On the other hand, no food as sample is a widespread stimulus with no specific behaviour associated with it.

Kendrick, Rilling, and Stonebraker (1981, Experiment 1) provided additional evidence indicating that matching performance was accurate when an F cue was followed by an unconditional discrimination. Pigeons were trained in a two choice DMTS with red and green lights as sample and comparison stimuli. Two experimental conditions were compared in an ABA experimental design. In the A condition, the F cue was followed by an unconditional discrimination in which one side key was illuminated by a white horizontal bar and the other side key by a white vertical bar. Regardless of the previous sample, a peck to the vertical bar always produced reinforcement, while a peck to the horizontal bar started the ITI. In the B condition, the F cue signalled the omission of the comparison stimuli. The effect of the omission or substitution of the comparison stimuli was evaluated during four probe trials within a session. The results indicated that when the F cue was followed by omission of the comparison stimuli, matching accuracy was reduced to near chance levels on probe trials. In contrast, there was no loss of matching accuracy after an F cue, when an unconditional discrimination was substituted for the comparison stimuli.

The previously described experiments (Maki & Hegvik, 1980, Experiment 2; Kendrick et al., 1981) suggest that the omission of the comparison stimuli might not be responsible for the decrement in DMTS performance on F cued probe trials. Instead, either the lack of an opportunity to perform choice responses or obtain reinforcement seems to be crucial. However, in the procedures mentioned earlier, the role of reinforcement and choice responses is not clear since the majority of the trials terminated with the execution of choice responses and reinforcement. To evaluate the role of choice responses, Maki, Olson, and Rego (1981) and Kendrick et al. (1981) modified the comparison substitution procedure. In the Maki et al. study, the comparison stimuli were replaced in each trial containing an F cue with a single stimulus to which a response was always reinforced. In the Kendrick et al. study, reinforcement after an F cue was delivered independently of responding. With these procedures a trial ended with reinforcement, but the choice response was eliminated. Replacing the comparison stimuli with a single stimulus or with an unconditional discrimination led to identical results, thereby suggesting that a choice between comparison stimuli is not a critical variable in producing the directed forgetting effect but the absence of reinforcement is.

Somewhat different results were reported by Grant (1981, Experiment 1). Pigeons were trained in a successive DMTS task with colours as sample stimuli. A vertical line (R cue) presented .5 sec after sample offset indicated that the memory of the sample would be tested by presenting the usual green or red comparison stimulus at the end of the retention interval. A horizontal line (F cue) signalled the irrelevance of the sample stimulus at testing. Forget cued trials terminated with the omission of the comparison stimulus for one group (no-test group). For the other group, the F cue indicated that the comparison stimulus would be substituted with a black dot signaling response-independent reinforcement (dot-test group). The control acquired by each of the cues was evaluated during probe trials where the comparison stimuli were presented following both F and R cues. The duration of the cues was manipulated during probe trials. Grant found that the discrimination index was significantly higher on R cued probe trials than on F cued probe trials. Performance was equally poor during F cued probe trials regardless of whether the F cue signalled the omission of the comparison stimuli or their substitution. The results using the comparison-substitution procedure contrast with those reported by Maki and Hegvik (1980), Maki et al. (1981), and Kendrick et al. (1981).

The reasons for this discrepancy are uncertain. Grant employed a successive DMTS task while all the others used a choice DMTS procedure. Other findings (e.g., those obtained with double cuing procedures; Stonebraker et al., 1981) suggest that the underlying processes in a choice DMTS task are the same as those operating in a successive DMTS task. However, it may be possible that the delivery of reinforcement independently of responding operates differently in the two paradigms. Another possibility is that the dependent measures in each task are not equally sensitive to the experimental manipulations.

II. TEMPORAL PARAMETERS OF F CUES.

In general terms, temporal parameters of the sample and the delay and intertrial intervals have been demonstrated to have an effect over short- and long-term memory. Regarding the study of short-term memory with a DMTS paradigm, it has been observed that matching accuracy is affected by the duration of the sample stimuli (Roberts & Grant, 1974; Roitblat, 1980), the length of the retention interval (Grant & Roberts, 1976; Roberts & Grant, 1974), and the length of the intertrial interval (Roberts, 1980; Santi & Grossi, 1981).

Parameters that have been demonstrated to be effective in controlling matching performance must be considered in the analysis of directed forgetting. The temporal parameters studied with single cuing procedures deal with the duration of the cues, the directed forgetting effect obtained depending on the length of the retention interval and the temporal position of the cues within the retention interval.

(1) DURATION OF THE CUE. Early studies using DMTS procedures have demonstrated that one of the variables controlling matching performance is the length of time that subjects are exposed to the sample stimuli. In those studies it was found that matching performance improves with increases in the duration of the sample (Herman & Gordon, 1974; Nelson & Wasserman, 1978; Roberts & Grant, 1974). To determine whether the duration of R and F cues has a similar effect over DMTS performance, Grant (1981, Experiment 1), in an experiment described earlier, manipulated the duration of the cues during probe trials. In any particular session, the duration of R and F cues was .5, 1, 2, or 3 sec. A 3 sec retention interval was used. The results indicated that the duration of the cue failed to affect performance. A

tentative explanation for the failure of the duration of the cue to affect DMTS performance in a way similar to the duration of the sample stimulus is that a different kind of information needs to be obtained from the sample stimulus than from the cue. Apparently, when a sample stimulus is presented, subjects gradually form a memory representation which is similar to the correct comparison stimulus. Supposedly, this is a complex process since the subject 'must identify the sample stimulus being presented, query long-term memory to retrieve the appropriate mapping rule, and then generate the representation of the correct test stimulus' (Roitblat, 1980, p. 349). Therefore, with increases in sample duration, this memorial representation becomes more fully developed increasing the probability of a correct match. In contrast, the cue is an instruction formed in an all or none fashion concerning trial outcome. "An informal way to describe an instruction is that the pigeon remembers 'what to do' rather than 'what it saw'" (Honig, 1978, p. 244). That is, after the cue presentation, the pigeon only needs to remember the signalled trial outcome; therefore the duration and all other components of the cue are irrelevant (Weisman & DiFranco, 1981).

(2) LENGTH OF THE RETENTION INTERVAL. In short-term memory research with animal subjects, it has been consistently reported that recall of stimuli is reduced if the retention interval is lengthened (Carter & Werner, 1978; Nelson & Wasserman, 1978; Roberts & Grant, 1974). Since the length of the delay interval is an important variable in determining retention, the effect of single cuing procedures has been studied using short and long delay intervals.

Maki and Hegvik (1980, Experiments 1 & 2), with a procedure described earlier, evaluated the effect of postsample cues on different retention interval lengths. They employed short (3 sec in Experiment 1 and 2 sec in Experiment 2) and long (6-15 sec in Experiment 1 and 5-9 sec in Experiment 2) delay intervals. Maki and Hegvik found that performance at long delays tended to be lower for both R and F cued probe trials. The directed forgetting effect was unreliable at short delay intervals; that is, performance on F cued probe trials was similar to performance on R cued probe trials at short delays. However, the directed forgetting effect was reliable at long delay intervals when food served as the sample stimulus. That is, performance was significantly lower on F cued probe trials than on R cued probe trials at long delays.

Grant (1981, Experiment 3) reported that when R, F, and no cue trials and 3 and 6 sec delay intervals were used, performance was influenced by trial type with no significant difference between R and no cue trials, each resulting in significantly better performance than on F cued trials at both delays. Increases in the length of the retention interval produced a drop in performance across all trial types. However, the decrease in performance on F cued probe trials was more pronounced at the long retention interval.

To summarize, the evidence indicates that the magnitude of the directed forgetting effect depends on the length of the delay interval. Long retention intervals produced a more marked directed forgetting effect than short retention intervals.

(3) TEMPORAL LOCATION OF THE CUE WITHIN THE RETENTION INTERVAL. The placement of the cues within the retention interval has been investigated in two studies using single cuing procedures. In Stonebraker and Rilling's (1981) experiment, pigeons were trained in a successive DMTS task with colour fields as sample stimuli and a vertical and a horizontal line as R and F cues, respectively. The retention interval was constant at 4 sec throughout the

experiment. Remember and forget cues were presented immediately after the sample offset in the first phase, and with a 3.5 or 2 sec delay after sample offset in the subsequent phases. The main result was that performance was better on R cued trials than on F cued trials, if the cues were presented early in the delay interval. However, as the presentation of the F cues was delayed within the retention interval, matching accuracy on F cued trials improved. Performance on R and F cued probe trials was nearly identical when the cues were presented 3.5 sec after the sample offset. No significant difference was found with any delay on R cued probe trials. Grant (1981, Experiment 2) found similar results by presenting the cues at the beginning, middle or end of a constant 3 sec retention interval. Performance was more accurate on R cued probe trials, and an F cue was less effective in producing forgetting if the delay between the sample and cue increased. No difference was found as a function of cue delay in R cued probe trials.

To conclude, matching performance is strongly reduced by F cues when those cues occur early in the retention interval. As the delay between the sample offset and cue presentation increase, F cues are less effective in reducing accuracy, and the decrement in performance produced by an F cue nearly disappears if the F cue is delayed until the end of a 3 or 4 sec retention interval.

III. DOUBLE CUING EXPERIMENTS.

The experiments discussed so far focus attention on the function of a single cue presented after the sample offset. In double cuing experiments two postsample cues are presented within the same retention interval. Grant (1981, Experiment 4), using a procedure similar to that used in his Experiments 1, 2 and 3, trained pigeons on forget-no cue, no cue-remember, and forget-remember cued trials. In forget-no cue trials, the 1 sec F cue was presented immediately following the sample offset. In no cue-remember trials, the 1 sec R cue was presented 1 sec after the sample termination. During forget-remember trials, the 1 sec F cue was presented after sample offset and was followed immediately by a 1 sec R cue. Three and six sec retention intervals were used. The cuing effects were evaluated in probe trials containing the comparison stimuli at the end of the delay interval.

Grant reported that retention was affected by trial type with forget-no cue trials yielding poorer performance than either the no cue-remember or forget-remember trials. The latter two did not significantly differ. Performance decreased as the retention interval increased; the drop in performance was greater on forget-no cue trials than on the other trial types. It was pointed out that the immediate presentation of an R cue can attenuate the effect of a prior forget cue.

A possible explanation of these findings is that this attenuating effect of R cues might be the result of the novelty of presenting two cues. If this suggestion is correct, then any stimulus which follows an F cue might attenuate the directed forgetting effect. Stonebraker et al. (1981, Experiment 2) trained pigeons with a choice DMTS procedure. Green and red keylights were used as sample and comparison stimuli and the R and F cues were a white circle and an equilateral triangle, respectively. The delay interval was 4 sec in duration. Four types of trials were used: Forget cue alone (FX), F cue followed immediately by an R cue (FR), F cue followed immediately by a novel stimulus (FN, white light on the center key), and remember cue alone (RX). The first cue (R or F) was presented immediately after the sample offset. Stonebraker et al. reported that 95% accuracy was achieved during R cued trials

(RX). Matching performance was inferior on F cued probe trials (67.5%) when compared to R cued probe trials. On FR probe trials, matching performance was restored to baseline levels (97.5%). Performance during FN probe trials did not return to baseline levels (77.5%). Even though the cancelling effect of a novel stimulus over an F cue was not as strong as the cancelling effect of an R cue, matching accuracy on FN trials was superior to single F cued trials. Based on these results, the authors concluded that the cancelling effect of R cues is attributable to the conditioning history of R cues. They suggested that, in RX trials, R cues acquired control over memory processes by predicting the presentation of the comparison stimuli. However, the presentation of a novel stimulus immediately after an F cue also reduced the directed forgetting effect, although to a lesser degree. Stonebraker et al. suggested two possible explanations for this result. First, it may be that some learning occurred on FN probe trials. This learning is possible since all FN trials terminated with the presentation of the comparison stimuli. An alternative account is that, perhaps some time is required for an F cue to terminate rehearsal "and the novel stimulus could have retroactively interfered with the processing of the F cue before rehearsal termination was complete" (Stonebraker et al., 1981, p. 391).

To investigate whether an F cue cancels a previous R cue, Grant (1981, Experiment 5) used remember-forget, remember-no cue and no cue-forget trials. Three and six sec delay intervals were employed; the procedure already described was used. Performance on remember-no cue. trials was significantly better at both delay intervals than performance on the other two trial types. At the 3 sec retention interval, performance was more accurate on remember-forget than on no cue-forget. Performance on remember-forget and no cue-forget was basically identical at the 6 sec retention interval. However, this may be the result of a floor effect since the discrimination indexes for these two conditions converged at the chance level.

Single cuing experiments in which the location of the cue was manipulated within the retention interval demonstrated that the temporal relation between sample offset and cue presentation was critical in affecting matching performance. To determine whether the temporal relationship between F and R cues is decisive in determining the cancelling effect of an R cue over an F cue, Stonebraker et al. (1981, Experiment 1) trained pigeons in a successive DMTS task using colour fields as sample stimuli and a vertical and a horizontal line as R and F cues, respectively. The duration of each cue was .5 sec throughout the experiment and the retention interval 4 sec. In the initial phase of training, R and F cues were presented immediately after the sample offset. Subsequently, in 50% of the trials, R and F cues were presented either .5 sec or 3.5 sec after the sample offset. The effect of each manipulation was evaluated during forget (XF) and forget-remember (FR) cued probe trials and standard R cued (XR) trials. During FR probe trials, either a 0 sec or 3 sec delay was used between F and R cues. The following results were reported: (1) Performance on XR cued trials was significantly better than performance on XF cued trials regardless of whether the cues were presented .5 sec or 3.5 sec after the sample offset; (2) performance on FR cued trials, when the R cue followed the F cue immediately, was nearly identical to R cued trials; (3) performance on FR cued trials, when the R cue was delayed until the end of the retention interval, was identical to performance on F cued probe trials. With regard to the first finding, it is interesting to note that in the Grant (1981) and Stonebraker and Rilling (1981) studies, when the F cues were delayed within the retention interval, matching accuracy improved to the point of being nearly identical to performance on R cued trials. By contrast, Stonebraker et al. (1981) found that performance on F cued trials was very similar regardless of whether F cues were delayed .5 sec or 3.5 sec within the retention interval (73% and 70%, respectively).

In summary, the evidence from experiments using postsample double cuing indicates that an R cue presented immediately after an F cue mitigates the decrement in matching performance produced by the F cue. Furthermore, the evidence suggests that this cancelling effect is not entirely a result of the novel situation produced by presenting two cues during the same retention interval, although the cancelling effect of a R cue appears to be dependent on the temporal relation between the two cues. On the other hand, an F cue presented immediately after an R cue is not as effective in reducing matching performance as it is when presented alone, if the delay interval is short.

IV. THEORETICAL INTERPRETATIONS OF THE DIRECTED FORGETTING PHENOMENON.

Several interpretations of the directed forgetting phenomenon have been proposed: (1) Disruption by novelty hypothesis, (2) contextual differences during retrieval, and (3) control of rehearsal process.

(1) DISRUPTION BY NOVELTY HYPOTHESIS. This explanation suggests that the poor matching performance after F cued probe trials results from the fact that the presentation of comparison stimuli subsequent to the F cue is a novel event producing the disruption of matching performance. In other words, during training the comparison stimuli were presented after R cues and omitted after F cues whereas during testing the F cues were occasionally followed by the comparison stimuli. Hence, poor matching accuracy on F cued probe trials may be the result of the novel situation produced by presentation of the comparison stimuli during F cued probe trials. If this hypothesis is correct, then similar or greater disruption should be produced by delaying the F cue within the retention interval (Stonebraker & Rilling, 1981). In other words, during training an F cue is followed only by a delay interval whereas during probe trials the comparison

stimuli occur after the delay interval. This novel situation may disrupt matching performance. Furthermore, if the F cue is presented at the end of the retention interval during probe trials, the comparison stimuli not only occur after an F cue but also occur in temporal contiguity with it. This latter situation is, perhaps, more novel if compared with training. Therefore, if the disruption by novelty account is correct, similar or greater disruption in performance is expected when an F cue and comparison stimuli occur together than when there is a delay between the two events.

According to this account of directed forgetting, performance on F cued probe trials should be poorer than performance on R cued trials regardless of the temporal position of F cues within the retention interval. However, the decline in performance should be more pronounced when F cues are delayed within the retention interval. In order to evaluate the disruption account, Stonebraker and Rilling (1981) and Grant (1981, Experiment 2) manipulated the temporal location of R as well as F cues within a constant length retention interval (4 and 3 sec, respectively). The data obtained were opposite to the predictions of the disruption by novelty hypothesis. In both studies it was reported that a forget cue was less effective in producing a decrease in matching performance when presented at the end of the delay interval than at the start. More explicitly, as presentation of the cues was delayed within the retention interval, matching accuracy on F cued trials improved. Performance on R cued probe trials was independent of the temporal location of the cue. These results suggest that the decrement in matching performance following an F cue presentation is not attributable to the unexpected occurrence of the comparison stimuli at the end of probe trials. However, it is noteworthy that results consistent with this hypothesis were reported by Stonebraker et al. (1981).

(2) CONTEXTUAL DIFFERENCES DURING RETRIEVAL. The context dependent retrieval hypothesis attributes the directed forgetting effect to a failure to retrieve the memory representation of the sample as a result of contextual differences between training and testing. Specifically, it is assumed that contextual events present during training are necessary to retrieve the required information at the moment of testing. Any event that has acquired control over responding, excluding the target discriminative stimulus, is part of the context (Rilling et

al., in press). Thus, events such as the relevant stimuli imposed by the experimental situation, the behaviour associated with those stimuli, and the stimuli produced by the behaviour are contextual events since they may have acquired control over responding. Contextual differences between training and testing conditions are variables in determining forgetting since it is hypothesized that contextual events are included with the discriminative stimuli of the learning task as attributes of the memory trace for an episode (Spear, 1971; 1978).

In directed forgetting experiments employing a DMTS task, there are many sources of contextual differences between R and F cued probe trials. Typically in an F cued trial, the opportunity to perform a response to the comparison stimuli is absent, the trial also terminates with the absence of reinforcement, and the F cue controls delay interval behaviour such as moving away from the key. By contrast, on an R cued trial, a response to the comparison stimuli is made, the trial terminates with the presence of reinforcement, and the R cue controls behaviour such as orientation towards the key. According to Rilling et al. (in press), the most important contextual difference between R and F cues is that they control different behaviour during the retention interval. They reported that following the R cues, all birds remained oriented toward the key and most of the subjects pecked at the dark key throughout the retention interval until the onset of the comparison stimuli. Following the F cue, pecking during the retention interval was terminated and the pigeon moved away from the key.

One of the critical aspects of this account of directed forgetting is the hypothesis that the directed forgetting effect may occur if the behaviour preceding the indicator response fails to occur at the time of the retention test (Rilling et al., in press). Thus, the poor performance on F cued probe trials is attributable to a retrieval failure since the behaviour previous to the comparison stimuli presentation occurs only in the context established by R cues. One of the most important criticisms of the context dependent retrieval account of directed forgetting is that the evidence to substantiate the hypothesis that R and F cues control different behaviour during the retention interval is based only on non-systematic observation.

One obvious implication of the assumption that retrieval of the representation of the sample stimulus is dependent on the context is that, as long as the proper context is maintained, retrieval of the sample stimulus will occur. Stonebraker et al. (1981, Experiments 1 & 2) and Grant (1981, Experiment 4) found that when an F cue was followed immediately by an R cue, performance was nearly identical to that found on R cued trials. Based on this outcome, it could be assumed that the presentation of an R cue immediately after an F cue restored the appropriate context to retrieve the memory of the sample stimulus. However, in the Stonebraker et al. (1981, Experiment 1) study, when a 3 sec delay was inserted between the F and the R cue, performance was similar to performance on F cued probe trials, even though they reported that the orientation towards the key was restored in both conditions.[1]

Some other findings are also not easily explained with the context dependent retrieval position. Grant (1981, Experiment 5) reported that, if, in a 3 sec delay interval, an F cue was presented immediately after an R cue, the F cue was unable to disrupt matching performance as much as it did on no cue-forget trials. If the context dependent retrieval hypothesis were correct, similar matching disruption should have been found on remember-forget and no cue-forget trials since, during testing, the contextual differences between remember-forget and no cue-forget trials were comparable.

Other findings that are not consistent with the predictions made by the context dependent retrieval hypothesis come from experiments in which the temporal location of R and F cues was manipulated (Grant, 1981, Experiment 2; Stonebraker & Rilling, 1981). The results indicated that, as the F cue presentation was delayed within the retention interval, matching performance on F cued probe trials improved. Since during F cued probe trials the comparison stimuli were presented, contextual differences relative to R cued trials between training and testing may be assumed, regardless of whether the F cue was presented at the beginning or the end of the retention interval. However, in spite of the contextual differences, DMTS matching performance improved, if the F cue was presented at the end of the retention interval. Furthermore, delaying R cues within the retention interval did not disrupt performance despite the fact that these cues were presented in a temporal position different from training.

The data obtained with comparison-substitution procedures are consistent with the context dependent retrieval account of directed forgetting. No loss of matching accuracy was obtained if an F cue was followed by either an unconditional discrimination (Kendrick et al., 1981; Maki & Hegvik, 1980) or a single stimulus to which a response was always reinforced (Maki et al., 1981). Clearly, the sources of contextual differences between R and F trials were diminished if, after an F cue, an opportunity to perform responses and obtain reinforcement was presented.

In summary, the findings with comparison-substitution procedures support the contextual account of directed forgetting. These findings indicate that matching performance on F cued probe trials is equivalent to that on R cued trials if after an F cue an unconditional discrimination (Kendrick et al., 1981; Maki & Hegvik, 1980) or a single stimulus is presented (Maki et al., 1981). In other words, when minimizing the contextual differences between training and testing, the directed forgetting effect is not obtained. Furthermore, the findings with double cuing procedures indicate that performance on FR cued probe trials, when the R cue is presented immediately after an F cue, is identical to performance on R cued trials, presumably because the appropriate context for retrieval of the memory of the sample is restored. However, some of the evidence presented is not easily explained by the context dependent retrieval hypothesis. When the R cue is presented 3 sec after an F cue, matching perfromance is equivalent to that on F cued probe trials despite the restoration of the context (i.e., the cue and the behaviour presumably associated with it). In addition, contextual differences may be assumed independently of whether an F cue is presented early or late in the retention interval, and in the former case F cues lead to poorer performance than in the latter.

(3) CONTROL OF REHEARSAL. A different interpretation of the directed forgetting phenomenon is provided by the rehearsal hypothesis. The rehearsal hypothesis assumes that the information extracted from the sample stimulus is maintained in short-term memory by rehearsal throughout the retention interval. According to this approach, forgetting occurs when rehearsal is interrupted (Bjork, 1972).

In accounting for the findings in directed forgetting, the rehearsal hypothesis suggests that postsample cues control rehearsal. Grant (1981, Experiment 1), with a DMTS procedure already described, found that the discrimination index was significantly higher on R cued trials than on F cued probe trials independently of whether the F cue signalled the absence of the retention test or the occurrence of another stimulus associated with non-contingent reinforcement. These results suggest that a sufficient condition to establish effective F cues is that they signal that the sample memory is irrelevant during the retention test. Grant (1981) concluded that a postsample F cue halts, or at least reduces, rehearsal of the sample stimulus.

The evidence to support the rehearsal hypothesis comes from the findings obtained with single cuing procedures in which the temporal position of the cues within the retention interval was manipulated. Stonebraker and Rilling (1981) and Grant (1981, Experiment 2) presented cues at the beginning, middle, or end of a constant length retention interval. The results indicated that matching was more accurate on R cued trials than on F cued trials, but as the delay between the sample offset and the presentation of the cue increased, matching accuracy on F cued probe trials improved. These findings are consistent with the assumption that F cues influence the rehearsal of the sample: "If the pigeon rehearses until the presentation of an F cue, which then terminates rehearsal, more forgetting should occur when the cue is presented at the beginning of the delay than at the end" (Stonebraker & Rilling, 1981, p. 200).

A second line of evidence to support the notion that postsample cuing affects rehearsal comes from double cuing experiments. Grant (1981, Experiment 4) and Stonebraker et al. (1981, Experiment 2) demonstrated that an R cue that immediately follows an F cue eliminates the effect of an F cue. If it is assumed that R cues maintain rehearsal whereas F cues terminate it, then the temporal relationship between an F and R cue should be a variable in determining the cancelling effects of an R cue over an F cue. The delayed presentation of an R cue after the termination of the F cue should be less effective in cancelling the F cue effect since, as the temporal distance between F and R cues increases, the likelihood of the sample being forgotten increases also. Stonebraker et al. (1981, Experiment 1) found that when the delay between F and R cues was 0 sec, performance was identical to R cued trials. Performance on forget-remember cued trials when a 3 sec delay was inserted between F and R cues was identical to performance on F cued probe trials. These findings are taken as evidence that postsample cues control the rehearsal process. In other words, it is hypothesized that if the presentation of an F cue halts or reduces the rehearsal process, the immediate presentation of an R cue after an F cue reestablishes the rehearsal process, which then is maintained throughout the retention interval (Stonebraker et al., 1981).

With the exception of the results reported by Grant (1981), all other findings with comparison-substitution procedures are contrary to the predictions of the rehearsal hypothesis. The evidence indicates that accuracy on F cued probe trials is basically identical to that on R cued trials if, after F cues an unconditional discrimination (Maki & Hegvik, 1980) or a single stimulus (Maki et al., 1981) is presented in the training phase. If F cues terminate rehearsal, then the substitution of comparison stimuli should not maintain high DMTS accuracy unless it is assumed that rehearsal is superstitiously maintained in the comparison-substitution procedure.

An extension of the hypothesis which suggests that postsample cuing procedures affect rehearsal is the suggestion that presample cuing may control rehearsal in a way similar to that demonstrated with postsample cuing procedures (Stonebraker et al., 1981). The evidence obtained with postsample double cuing procedures suggests that both F and R cues acquire stimulus control over the active processing which occurs during the delay interval. Clearly, the control acquired by postsample cuing must be over postsample processes, while presample cuing may influence encoding as well as rehearsal or retrieval. To determine if presample cuing control is exerted only over encoding or over postsample processes, Stonebraker et al. (1981, Experiment 3) trained six pigeons with a successive DMTS procedure. Samples of food and no food were used to signal the choice between green and red comparison stimuli. A vertical and a horizontal line functioned as R and F cues, respectively. An R cue signalled the presence of a retention test at the end of the delay interval. An F cue signalled the omission of the comparison stimuli at the end of the delay interval. A training session consisted of 88 presample R and F trials. Performance on the 44 presample R cued trials in a testing session was considered the baseline for that session. Three types of probe trials were used: presample F (pre F), presample F postsample R cue (pre F-post R), and presample R postsample R (pre R-post R). Four of the 88 trials were probe trials in a testing session.

The results were as follows: (1) Performance in presample F cued probe trials (61%) was reduced compared to performance on baseline presample R cued trials (87%); (2) accuracy in pre F-post R trials (71%) was not as poor as on pre F cued trials (61%). However, performance was not as accurate as on pre R-post R (91%) cued trials; (3) there was no overall decrement in accuracy (91%) in pre R-post R trials relative to baseline presample R (90%) cued trials.

The authors concluded that presample cues control matching performance in a fashion parallel to that of postsample cues. For four of the birds, matching accuracy in presample F cued probe trials (61%) was reduced relative to presample R cued baseline (87%) trials within the same session. Second, stimulus control by presample F and R cues was not established as reliably as with postsample cuing. Two of the birds did not show any loss in matching performance on presample F cued probe trials. Third, the most plausible explanation for the inability of a postsample R cue to completely attenuate the effects of a presample F cue is different encoding of sample stimuli previous to the presentation of a postsample R cue. If trials are presample cued and encoding occurs when the sample is presented, it would be more economical to encode only samples that will be tested for memory; that is, R cued samples. Fourth, presample cuing affects not only the encoding of the sample but also processing during the retention interval. This conclusion is based on the finding that a presample F cue, when followed by a postsample R cue, is less effective in reducing matching accuracy (71% in pre F-post R vs. 61% in pre F).

Several criticisms should be taken into account in evaluating the outcomes of the Stonebraker et al. (1981, Experiment 3) study. First, two of the subjects were not tested on pre F-post R and pre R-post R because matching performance on pre F cued probe trials was above 70% accuracy (about 72% and 95%, respectively). This criterion is inconsistent with that used in Experiments 1 and 2 in the same study. Second, the differences in matching accuracy among pre F (61%) and pre F-post R (71%) seem insufficient to support the conclusion that a presample F cue, when it is followed by a postsample R cue, is less effective in decreasing matching accuracy. In addition, not all subjects showed an increase on pre F-post R cued probe trials. Third, no statistical analysis was performed on the data.

V. ROLE OF R CUES ON DIRECTED FORGETTING.

In the study of directed forgetting it has been pointed out that both R and F cues control short-term memory processes (Bjork, 1972; Grant, 1981; Maki & Hegvik, 1980; Rilling et al., in press; Stonebraker et al., 1981). According to the rehearsal hypothesis, an R cue maintains rehearsal of the memory of the sample throughout the retention interval whereas an F cue terminates or decreases rehearsal. On the other hand, the context dependent retrieval hypothesis assumes that an R cue maintains the approprite context to retrieve the memory of the sample whereas an F cue establishes the context in which the memory of the sample is not retrieved. However, the control of R cues over DMTS performance has not been consistently demonstrated with a single cuing procedure. Stonebraker and Rilling (1981) and Grant (1981, Experiment 2) reported no difference between R cued trials when the R cues were presented in the beginning, middle, or end of a constant retention interval.

Using a procedure similar to that employed in his first experiment, Grant (1981, Experiment 3) compared matching performance among R, F, and no cue probe trials at 3 and 6 sec retention intervals. He reported similar matching accuracy in R cued trials and no cued trials. Grant suggested that no cue might function as an implicit remember cue as a result of prior training, thereby accounting for the absence of a difference between R cued and no cue trials. Recently, Maki et al. (1981) reported that in a comparison-omission procedure, DMTS performance on R cued trials was significantly better than on no cue probe trials if food samples and long retention intervals are used.

The evidence of control exerted by R cues over DMTS performance comes from double cuing experiments. Grant (1981, Experiment 4) and Stonebraker et al. (1981) showed that performance on forget-remember cued trials was identical to performance on no cue-remember cued trials. Accuracy decreased as the retention interval increased, and the drop in performance was greater on forget-no cue trials than on the other trial types. Thus, an R cue exerts control over matching performance by attenuating the effect of a previously presented F cue.

Besides the attenuating effect of an R cue over the effect of an F cue, an R cue seems to protect or insulate memory from a reduction of processing which accompanies the presentation of an F cue (Grant, 1981, p. 37). Grant (1981, Experiment 5) using remember-forget, no cue-forget and remember-no cue trials found that performance was influenced by trial type, mainly at 3 sec delay intervals. He observed that an F cue presented after an R cue was less effective in reducing matching accuracy than an F cue following a no cue.

The aim of the present research is to provide further evidence regarding the role of R cues on pigeons' short-term memory. One of the primary issues of concern deals with which manipulations are required to demonstrate that an R cue functions differently from a no cue condition using a single cuing procedure. In addition, the possibility that the control demonstrated by R cues in a double cuing procedure may be the result of the novelty of the situation with two cues will be re-examined.

EXPERIMENT 1.

In directed forgetting research, the role of explicit R cues on DMTS performance is as yet unclear. The results with single cuing procedures and visual samples indicate that a postsample F cue halts or reduces rehearsal whereas a postsample R cue does not exert any differential control over postsample processes relative to a no cue condition (Grant, 1981; Stonebraker & Rilling, 1981). In contrast, the results with double cuing procedures indicate that an R cue has an attenuating effect over a previously presented F cue (Grant, 1981, Experiment 4; Stonebraker et al., 1981, Experiment 1).

The outcomes obtained with single cuing procedures indicated that matching accuracy was essentially equivalent on probe trials when the R cues were presented at varying delays within a constant retention interval whereas matching accuracy on F cued probe trials improved when the F cues were presented at the end of the retention interval (Grant, 1981, Experiment 2; Stonebraker & Rilling, 1981). Grant (1981, Experiment 3) found a decrement in matching performance on F cued probe trials when compared with R cued and no cue trials. On R cued and no cue probe trials matching accuracy was basically the same at 3 and 6 sec retention intervals. To explain why performance on remember and no cue probe trials was equivalent, Grant (1981) suggested that a no cue might have functioned as an implicit cue to remember. In the Stonebraker and Rilling and Grant experiments, the DMTS task was initially established and performance was maintained at a prespecified criterion without any cues (i.e., a no cue condition). In the second phase, the forget and remember cues were introduced and their functions specifically trained. Thus, an F cue signalled the irrelevance of the sample in all three experiments, whereas both the absence of any cue, and a R cue signalled that the comparison stimuli would be presented and the sample stimulus tested for recognition. Apparently, the signal property of the no cue was established during initial training in the DMTS task.

If a no cue functions as an implicit R cue, then in experiments where the temporal position of the cues was manipulated, the lack of control shown by R cues as well as the control shown by F cues over matching performance is explicable. There was no overall matching performance decrement as the R cue was delayed within a constant retention interval because the absence of a cue was functioning as an implicit cue to remember. Secondly, performance on F cued probe trials improved as the F cue was delayed because the sample was being rehearsed by virtue of the presence of an implicit R cue (i.e., the absence of a cue). Rehearsal of the sample terminated when the F cue was actually presented.

One way of testing whether the hypothesis advanced by Grant (1981) is correct is to provide subjects with sufficient training in a no cue condition where the absence of an explicit cue is followed by the omission of the comparison stimuli. If control of an R cue over DMTS performance has not been demonstrated in single cuing experiments because of the presence of a no cue functioning as an implicit R cue, and this implicit no cue function to remember was established during previous training, then in conditions where the no cue functions as an implicit forget cue, the control over DMTS exerted by an R cue should be demonstrable even in single cuing procedures.

The purpose of this experiment was to determine whether control over performance by an R cue with a single cuing procedure could be obtained by establishing the no cue as an implicit cue to forget. Subjects were provided with sufficient training in a procedure where both F cues and no cues indicated the absence of a retention test at the end of the delay interval. The cuing effect was evaluated during R, F, and no cue probe trials where the cues were presented either in the beginning, middle, or end of a 3 sec retention interval. If the no cue condition functions as an implicit F cue, then matching performance on R cued probe trials would be expected to be the best when R cues are presented immediately after the sample termination, and decline as the delay between sample and R cue increases. Matching performance on F cued and no cue probe trials should be equivalent at all cue delays, and poorer when compared with performance on R cued probe trials, if the R cue was presented in the beginning of the retention interval. At the longest delay between sample and R cue (2 sec), performance on R, F, and no cue probe trials should converge.

METHOD

Subjects. The subjects were 5 white Carneaux pigeons maintained at 80% ± 15 g of their free feeding weight and housed individually with constant access to grit and water. All subjects had extensive experience with a choice DMTS task involving colour and line stimuli as well as compound stimuli (Santi, Grossi, & Gibson, in press).

Apparatus. The apparatus consisted of four Coulbourn modular operant test chambers (Model No. E10-10) housed individually in isolation cubicles (Model E10-20). Each experimental chamber was equipped with three clear acrylic pecking keys. The stimuli (red, green, black dot on white background, a horizontal or vertical line) were displayed by IDD projectors behind the keys onto a frosted rear projection screen (Coulbourn Model E21-18). Directly below the center key was a 5.7 x 5 cm opening which provided access to a hopper filled with mixed grain. General illumination was not provided. All the experimental manipulations and data collection were arranged and recorded by a microcomputer system based on an M6800 microprocessor.

Procedure. During the training phase of the experiment, all birds were trained in a 3 sec DMTS task with cues signalling how a trial would end. Remember, forget, and no cue trials were used. Each session consisted of 132 trials divided into 11 blocks of 12 trials each. Within each block, each combination of sample and correct side key and each of the three cues occurred once in a random sequence. Each trial began with a warning signal (a black dot on a white background) presented on the center key. A peck to it immediately produced a red or green sample stimulus. The sample stimulus was presented on the center key for 5 sec. The offset of the sample was followed by a 3 sec retention interval. Interpolated within the retention interval was either a vertical line, a horizontal line or a no cue (i.e., the absence of any signal) stimulus which predicted the occurrence (R cue) or nonoccurrence (F cue and no cue) of the comparison stimuli. The cue was presented immediately after the termination of the sample stimulus and was 1 sec in duration. The reason for presenting the cues immediately after sample termination was to prevent further processing of the sample stimulus before the presentation of R and F cues. In other words, it was hypothesized that if the explicit cue to remember or forget was delayed within the retention interval, a certain amount of processing might occur in the absence of a signal (i.e., during no cue) while the subject was waiting for the presentation of the cue. If this processing during the delay between sample and cue actually occurred, it might obscure differences which exist between the conditions or, more explicitly it might induce subjects to treat a no cue as an implicit R cue. The comparison stimuli were presented on the side keys after the 3 sec retention interval if the sample was followed by an R cue. A single peck to the stimulus that matched the sample resulted in 4 sec access to mixed grain. A peck to the comparison stimulus that was not identical to the sample turned the comparison stimuli off and a 4 sec blackout occurred. Following either reinforcement or nonreinforcement, an intertrial interval of 20 sec occurred, during which time the houselight was not illuminated. In contrast, if the sample was followed by an F cue or no cue, the comparison stimuli were omitted following the 3 sec interval. Following F and no cue trials, an intertrial interval of 24 sec spent in darkness occurred. For three of the birds, the R cue was the vertical line and the F cue was the horizontal line. For the other two pigeons, the cue function was reversed. The no cue was the absence of any signal for all birds. The training phase lasted 30 sessions during which accuracy on R cued trials was at least 80% in the last three sessions.

Testing. The cuing effect was evaluated during R cued, F cued and no cued probe trials. Each testing session consisted of 11 blocks of 12 trials each (132 trials). The first 2 blocks in each session contained only standard trials (i.e., trials as described in the training phase). The subsequent 9 blocks contained 8 standard trials and 4 probe trials in each block of 12 trials (36 probe trials per session). The testing phase was identical to the training phase with two exceptions. First, the comparison stimuli were presented following the retention interval on all probe trials regardless of the nature of the cue presented. That is, on forget and no cue probe trials, red and green comparison stimuli were presented, rather than cancelled, and correct responses were reinforced. Second, on probe trials, randomized within blocks of 3 sessions, forget and remember cues were presented during either the beginning, middle, or end of the 3 sec retention interval. That is, the 1 sec cue was presented immediately, 1 sec, or 2 sec after sample termination. On no cue probe trials, the comparison stimuli occurred at the end of the 3 sec retention interval. However, for analysis purposes, the no cue was treated as occurring equally frequently in the beginning, middle, or end of the retention interval. Thus, in a given session if R and F cues were presented in the beginning, then the temporal location of a no cue would be considered as being in the beginning as well. The testing phase terminated when the data of 12 sessions had been collected.

RESULTS

Separate analyses of variance, using only probe trial data, were performed for percent of correct matching responses and latency of correct responses.[3] The data were analyzed according to replication (1, 2, 3, or 4), type of cue presented (R, F, or no cue), and temporal position of the cue (beginning, middle, or end). For all results described, the rejection level was set at .05.

Percent of correct matching responses. Figure 1 presents the mean percent of correct matching responses during the last 3 training sessions, and during the testing phase, averaged across the four replications. The analysis of variance with probe data revealed a statistically significant effect of replication, F (3, 140)= 6.69, cue, F (2, 140)= 8.94, and position, F (2, 140)= 7.04. None of the interactions were statistically significant (see Appendix A). To determine which means differed significantly, Tukey's HSD multiple comparison tests were conducted using the .05 level of significance.[4] In Table 1 the mean of correct responses for replications, cues, and temporal position of the cues are shown. The analysis performed as a function of replication showed that accuracy tended to improve over blocks of sessions. A statistically significant difference was obtained comparing replication 1 with 4, 2 with 4, and 3 with 4. Although all other pairwise comparisons were not statistically significant, it is worth noting that from replication to replication the improvement in DMTS accuracy was small but consistent (see Table 1).

The multiple comparison test for the accuracy data as a function of cue indicated that performance on F cued probe trials was significantly lower than performance on R and no cue probe trials. The difference between performance on R and no cue probe trials was not reliable.

The Tukey's HSD test revealed that accuracy tended to decrease as the delay between sample and cue increased. When the cue was presented in the beginning of the retention interval, accuracy was significantly higher than when the cue was presented in the middle or end, with no significant difference between middle and end.

Latency of correct responses. The analysis of variance performed on these data indicated no significant main effects or interactions (see Appendix B).

DISCUSSION

The most significant finding in the present experiment was the failure to establish a forget function for the no cue condition. The analysis indicated that DMTS accuracy on no cue probe trials was statistically equivalent to that on R cued probe trials in spite of explicit training of the no cue condition to function as an implicit cue to forget. This outcome is contrary to expectations based on Grant's (1981) suggestion that DMTS performance on no cue and R cued probe trials was identical since as a result of previous training, the no cue was functioning as an implicit remember cue. The fact that accuracy on F cued probe trials was lower than on R cued probe trials is consistent with either the suggestion that F cues reduce performance by signalling the irrelevance of the sample at the moment of testing (Grant, 1981), or the omission of the comparison stimuli and reinforcement at the end of the trial (Maki & Hegvik, 1980; Maki et al., 1981). However, if this is a reasonable explanation of the directed forgetting effect, then a similar reduction in performance on no cue probe trials should have been obtained by omitting the comparison stimuli after a no cue.

In an attempt to explain this outcome, several alternatives are considered. The most obvious account for the failure of a no cue to control matching accuracy in a way similar to that of an F cue is that the amount of training provided was insufficient. Two reasons as to why this was not the case need to be mentioned. First, there is some evidence indicating that a few training sessions with a comparison omission procedure are sufficient to alter instructional processes. Reduced matching accuracy was obtained regardless of whether a maximum of 12 (Maki, Gillund, Hauge, & Siders, 1977) or 27 (Santi, Tombaugh, & Tombaugh, in press) training sessions of a comparison omission procedure were employed. Second, 30 sessions omitting the comparison stimuli on F cued trials were sufficient to reduce DMTS accuracy following F cues. There is no theoretical reason or empirical evidence to suppose that a decline in accuracy in a no cue condition is governed by a length of training different than that of F cues.

Perhaps the similar DMTS performance on R and no cue probe trials is due to the fact that the directed forgetting effect is asymmetrical and time dependent. Maki and Hegvik (1980) and Maki et al. (1981) pointed out that the size of the decrease in performance following F cues depends on the length of the retention interval as well as the type of sample stimulus (food or no food). Furthermore, the only published evidence that performance on R and no cue trials may differ in a single cuing procedure indicates that DMTS accuracy is reliably poorer following no cue probe trials than following R cued trials if the retention interval is long and food used as the sample stimulus (Maki et al., 1981). It seems that the asymmetrical effect of F cues is unique to the procedures employed by Maki and Hegvik (1980) and Maki et al. (1981) since other authors have reported symmetrical effects using visual samples (Grant, 1981; Stonebraker & Rilling, 1981; Stonebraker et al., 1981). However, it is uncertain whether performance differences between no cue and R cued trials is the result of combining the use of food as a sample stimulus and long retention intervals. Further research is required to determine the role of food samples and the length of the retention interval in the differentiation of performance between no cue and R cued trials.

The data obtained as a function of cue position suggest that some control over DMTS performance was achieved by omitting the comparison stimuli in the no cue condition. It may be argued that the no cue condition functioned as an implicit cue to forget since accuracy declined as a function of the temporal position of the R cue (see Fig. 1). However, several reasons as to why this interpretation is untenable need to be discussed. First, no difference in DMTS accuracy between no cue and R cued probe trials was found. Considering that accuracy as a function of type of cue is the primary measure of the cuing effect in a two choice DMTS task, it would be expected that if the no cue condition had been established as an implicit forget cue, then this control would primarily be reflected in accuracy as a function of the type of cue, and subsequently in accuracy as a function of the temporal position of the cue. Second, although presenting the cues either in the middle or end of the retention interval, as opposed to the beginning, significantly lowered matching performance, accuracy did not differ between middle and end. If the no cue condition had been functioning as an implicit forget cue, then because subjects spent more time without rehearsing the sample stimulus, the decrease in performance should have been more pronounced when R cues were presented in the end of the retention interval than when the cues were presented in the middle. However, it may be possible that the retention interval was not sufficiently long to be sensitive to these differences. Third, the decrease in performance as a function of the position of the cues was found for all types of probe trials. Recall that for analysis purposes, the no cue condition was considered to occur in the beginning, middle, or end of the retention interval depending on the temporal position of R and F cues on that particular testing session. Empirically, the no cue condition occurred throughout the retention interval in all no cue probe trials. Delaying R and F cues within the retention interval should have only decreased performance on R cued probe trials. Performance on F and no cue probe trials should not have been affected.

An alternative explanation of these data is that the novel situation of delaying R and F cues within the retention interval produced a general disruption of DMTS performance. According to the disruption by novelty account it would be expected that the presentation of the cues in a temporal position different to that used during training would disrupt performance. This notion is supported by the fact that accuracy for all probe trials (R, F, and no cue) was poorer when R and F cues were presented in the middle or end of the retention interval than when they were presented in the beginning. However, from this point of view, it is not clear how the equivalent performance between middle and end should be interpreted. If it is assumed that the presentation of the cues in the middle of the retention interval was as novel as the presentation of the cues at the end, then similar performance would be expected in both conditions. Nevertheless, it seems more plausible to assume that the occurrence of a cue in the end of the delay interval is more novel than the occurrence of the cue in the middle. When the cue was presented at the end of the delay interval, the cue occurred not only in a novel temporal position but also in temporal contiguity with the comparison stimuli. If this assumption is correct, then the presentation of the cues at the end of the retention interval should have produced a greater disruption of performance than the presentation of the cue in the middle.

Clearly, the effects of temporal placement of the cues are not entirely consistent with any of the hypotheses discussed. In addition, no other authors have reported a similar disruption in performance when the temporal position of the cues was manipulated; rather performance in earlier studies tended to improve with delay of F cues (Grant, 1981; Stonebraker & Rilling, 1981).

The effect of the cues was one of the major concerns of the present experiment. Previous data obtained with human (Horton & Petruk, 1980; Timmins, 1974) as well as with animal subjects (Grant, 1981; Maki & Hegvik, 1980; Maki et al., 1981; Rilling et al., in press; Stonebraker & Rilling, 1981; Stonebraker et al., 1981) have demonstrated that performance on F cued probe trials is inferior to performance on R cued probe trials. Consistent with those findings, the present research showed that F cues led to lower accuracy than R cues or no cues. However, contrary to the Maki et al. (1981) results, no evidence was obtained that omission of the comparison stimuli increases the latency of choice responses.

Although statistically significant, the decline in DMTS performance following F cues was small (see Table 1). Maki and Hegvik (1980), Maki et al. (1981), and Grant (1981) showed that the magnitude of the directed forgetting effect is dependent on the length of the delay interval employed. That is, to explain the small directed forgetting effect, it can be argued that the delay interval between cue termination and the presentation of the comparison stimuli was too short. The F cue was effective in reducing processing during the retention interval but perhaps it takes some period of time for the memory of the sample to be forgotten. If this notion is correct, then the probability of selecting the correct comparison stimulus during testing would be higher after short delays than after long delays.

An additional finding of the present experiment was that DMTS accuracy tended to increase over blocks of testing sessions. From replication to replication, performance improved not only on F cued probe trials but also on R and no cue probe trials.

EXPERIMENT 2.

Experiment 1 demonstrated that despite the omission of the comparison stimuli on no cue trials, the no cue condition was not established as an implicit cue to forget. The subjects used in Experiment 1 had extensive experience on a DMTS task prior to the experiment; thus, it is possible that once the no cue condition has been established as an implicit cue to remember, the effect is irreversible. If this is the case, an alternative procedure to establish a no cue function to forget would be to train naive subjects with all trials cued from the outset. If the assumption that control over matching performance by R cues has not been demonstrated because of the presence of a no cue functioning as an implicit R cue, then, when the development of this function is prevented, control over DMTS performance by R cues should be obtained. The purpose of Experiment 2 was to determine if training subjects with R and F trials cued from the outset was a sufficient condition to establish control of R cues over DMTS performance using a single cuing procedure. The cuing effect was evaluated during R, F, and no cue probe trials. On probe trials, the cues were presented either at the beginning, middle or end of a 3 sec retention interval. If a no cue implicit function to forget is established as a result of preventing rehearsal of the sample in the absence of an explicit cue to remember, then matching performance on R cued probe trials would be expected to be superior to performance on no cue and F cued probe trials when the R cues are presented immediately after the sample termination, and decline as the delay between sample and R cue increases.

METHOD

Subjects. The subjects were 5 experimentally naive white Carneaux pigeons maintained at 80% ± 15 g of their free feeding weight and housed individually with constant access to grit and water.

Apparatus. The apparatus were identical to that employed in Experiment 1.

Procedure. The five naive animals were adapted to the experimental chambers and trained to eat out of the hopper. Pecking to the response keys was then autoshaped. A red or green light were presented equally often on the left or right keys. The key remained illuminated for 8 sec if no response occurred. Following the key light termination, 4 sec access to mixed grain occurred. If the illuminated key was pecked within 8 sec, the reinforcer was presented immediately and the key light terminated. Each session of autoshaping consisted of 120 trials with an intertrial interval (ITI) of 30 sec. When a bird pecked the key on more than 80% of the trials within a session, autoshaping was terminated for that bird. A mean of 3.6 (range 3-4) sessions were required for autoshaping.

Training. A choice DMTS task was instituted following autoshaping. Each trial began with a warning signal (i.e., a black dot on a white background) presented on the center key. A peck to it immediately produced a red or green sample stimulus. The sample stimulus was presented on the center key for 5 sec. The offset of the sample was followed by a 1 sec delay interval, during which time a vertical line or a horizontal line was presented on the center key. The duration of the cue remained constant at 1 sec during the whole experiment. For three of the birds, the R cue was the vertical line and the F cue the horizontal line. For the other two birds, the function of the cues was reversed. If the sample stimulus was followed by an R cue, the comparison stimuli were presented on the side keys immediately after the R cue termination. A single peck to the stimulus that matched the sample resulted in 4 sec access to mixed grain. A peck to the comparison stimulus that was not identical to the sample produced 4 sec blackout. Following either reinforcement or blackout, a 20 sec ITI occurred, during which time the houselight was not illuminated. Alternatively, if the sample was followed by an F cue, the comparison stimuli were omitted. Immediately after the F cue termination, an ITI of 24 sec spent in darkness occurred.

Each session consisted of 120 trials. Sixty trials were R cued and 60 trials were F cued. When 80% accuracy on R cued trials was achieved for three consecutive days, the birds were trained to tolerate progressively longer delays. A mean of 12.2 (range 8-18) sessions were conducted before the delay interval was increased. The retention interval was increased by 1 sec contingent on criterial performance until the terminal 3 sec delay interval was achieved. Criterial performance to increase the retention interval was defined as 80% accuracy on R cued trials for three consecutive sessions. A mean of 11 sessions (range 8-13) was conducted in this condition. Once the criterial performance at 3 sec delay was achieved, 10 sessions were conducted for three of the subjects and five for the other two. This difference occurred because acquisition for three of the birds was faster than for the other two. The 120 trials in a session were divided into 15 blocks of 8 trials in each. Within a session, each sample-comparison configuration was presented 15 times with R cues.

Testing. The control over matching performance exerted by R and F cues was evaluated during R cued, F cued and no cued probe trials. The testing procedure employed in this experiment was similar to that described in Experiment 1. During F cued and no cued probe trials, the comparison stimuli were presented rather than omitted. The cues were presented in the beginning, middle or end of the 3 sec retention interval, randomized within a block of 3 sessions. Each testing session consisted of 124 trials divided into 11 blocks. The first 2 blocks in each session contained only R and F cued standard trials (i.e., 8 trials as described in the training phase). The subsequent 9 blocks contained 8 standard trials and 4 probe trials in each block of 12 trials (36 probe trials per session). Twelve testing sessions were conducted.

RESULTS

Separate analyses of variance, employing only probe trial data, were computed for percent of correct matching responses and latency of correct responses. Replication, type of cue presented, and temporal location of the cue were used as factors. The rejection level was set at .05 for all results reported.

Percent of correct responding. Figure 2 presents the mean percent of correct matching responses during the last 3 training sessions, and during the testing phase, averaged across the four replications. The analysis of variance employing only probe data revealed a significant effect of cue, _F_ (2, 140)= 6.79, and position, _F_ (2, 140)= 4.50. In contrast with Experiment 1, the effect of replication was not statistically significant, _F_ (3, 140)= 1.74. None of the interactions were statistically significant (see Appendix C). To ascertain which means differed significantly, Tukey's HSD multiple comparison tests were performed employing the .05 level of significance. Table 2 presents the means and standard deviations of percent correct matching as a function of replications, cues, and temporal position of cues.

The Tukey's HSD test for the accuracy data, as a function of cue, revealed that performance was significantly lower on F cued probe trials than on no cue, or R cued trials. No significant difference was found between performance on R and no cue probe trials.

The multiple comparison test performed as a function of position of the cue indicated that accuracy tended to decrease as the delay between sample and cue increased. When the cue was presented in the beginning of the retention interval, accuracy was significantly higher than when the cue was presented at the end. None of the remaining pairwise differences were reliable.

Latency of correct responses. Figure 3 presents the mean latency of correct responses during the last 3 training sessions and during the testing phase, averaged across the four replications. The analysis of variance performed on probe data indicated a significant effect of replication, _F_ (3, 140)= 2.74, and cue, _F_ (2, 140)= 58.33. No other effects were significant (see Appendix D). To ascertain which means were significantly different, Tukey's HSD multiple comparison test were conducted using latency data as a function of replication and cue. In Table 4 the mean latency of correct responding and standard deviations for replications, cues and temporal position of the cues are shown.

For latency as a function of replication, the multiple comparison test indicated that the latency of correct responses was significantly higher in the first replication than in the second. No other pairwise comparisons were significant.

The analysis performed as a function of cue indicated that latencies of correct responses for F cued probe trials were significantly longer than no cue and R cued probe trials. In addition, latencies of correct responses for no cue probe trials were significantly longer than for R cued probe trials.

DISCUSSION

The main contribution of the present experiment is the demonstration that performance on R cued probe trials is statistically equivalent to that on no cue probe trials despite cuing R and F trials from the start. In other words, although no cue trials were not presented during any phase of training, this did not prevent the no cue from functioning as an implicit R cue. To explain the identical performance on R and no cue probe trials, it may be argued that the subjects learned in one trial that a no cue was always followed by the presentation of the comparison stimuli since all no cue trials were probe trials. The results of the previous experiment suggest that this possibility is somewhat unlikely. In Experiment 1, it was shown that performance on R and no cue probe trials was equivalent even when accuracy tests for no cue trials (i.e., no cue trials followed by the presentation of the comparison stimuli) were interspersed among no cue regular trials (i.e., no cue trials followed by the omission of the comparison stimuli). Furthermore, if the subjects learned to rehearse the sample stimulus on no cue probe trials because they learned that a no cue was always followed by the presentation of the comparison stimuli, then delaying the presentation of the F cue within the retention interval should have produced performance similar to that on no cue or R cued probe trials.

It was pointed out previously that perhaps differences in performance between no cue and R cued probe trials can be achieved only if long retention intervals are used. This suggestion is supported by the fact that the only evidence indicating that performance on R and no cue trials may differ was obtained with food samples at long but not at short delay intervals (Maki et al., 1981).

As shown in the previous experiment, DMTS accuracy on F cued probe trials was significantly lower than on no cue or R cued probe trials. The magnitude of the directed forgetting effect was again small, which is consistent with the evidence that the size of the directed forgetting effect is dependent on the length of the retention interval (Grant, 1981; Maki & Hegvik, 1980; Maki et al., 1981).

Contrary to the findings in Experiment 1, correct choice responses on F cued probe trials had longer latencies than on either no cue or R cued probe trials. In addition, latencies to select the correct comparison stimulus on no cue probe trials were longer than those on R cued probe trials. Maki et al. (1981, Experiment 1) also found an increase in overall choice latencies on F cued probe trials when compared with those on no cue probe trials. Unfortunately, no data regarding the effect of R cues on latencies were reported.

It is uncertain why correct choice responses were made more slowly on no cue and F cued probe trials than on R cued probe trials. Perhaps this outcome was a consequence of the novel presentation of the comparison stimuli following F cues, and the novel presentation of no cue trials during the testing phase, respectively. Furthermore, choice latencies were significantly shorter during the second replication than during all others. The factors responsible for this outcome are unknown.

Regarding the position of the cue within the retention interval, the pattern of results obtained in the present experiment was similar to that of the previous one. For all cues, DMTS accuracy declined as a function of the temporal position of such cues within the retention interval (see Table 2). However, in contrast with Experiment 1, the difference between beginning and middle was not reliable. The fact that performance was lowered by presenting the cues at the end of the retention interval as opposed to the beginning is, perhaps, the result of a general disruption of DMTS performance. However, further research is required to determine whether this account is correct.

In summary, the present experiment demonstrated that, in spite of cuing R and F trials from the outset, a no cue did not come to function differently from an R cue, as indicated by the identical performance on R and no cue probe trials. Second, consistent with the evidence reported in the literature, DMTS accuracy on F cued probe trials was poorer than on no cue or R cued probe trials. Third, postsample cues had differential effects on latencies to select the correct comparison stimulus. The longer latencies on F cued and no cue probe trials when compared with those on R cued probe trials were interpreted to be a consequence of the novel presentation of the comparison stimuli after an F cue, and the novel presentation of no cue trials during the testing phase, respectively.

EXPERIMENT 3.

It was mentioned earlier that the evidence of control exerted by R cues over DMTS comes from double cuing experiments. Grant (1981, Experiment 4) showed that when an R cue was presented immediately after an F cue, matching performance was significantly better than on forget-no cue probe trials. However, it may be that the attenuating effect of R cues after F cues is the result of the novelty of the situation with two cues. In other words, perhaps any stimulus presented after an F cue cancels the effect of an F cue since, during training, subjects experienced only one cue in each trial while, during testing, subjects were exposed to two cues within a retention interval.

The evidence provided by Stonebraker et al. (1981, Experiment 2) suggests that the attenuating effect of R cues is the result of conditioning history. They pointed out that when an R cue was presented immediately after an F cue, matching performance was restored to baseline levels (97.5% accuracy). By contrast, when an F cue was followed by a novel stimulus, the cancelling effect of a novel stimulus over an F cue was not as strong as the cancelling effect of an R cue. In the latter case, matching accuracy (77.5%) was below performance on R cued trials alone.

Even though the evidence suggests that the cancelling effect of an R cue over an F cue is the result of conditioning history rather than the novelty of the situation with two cues, some considerations must be taken into account before the novelty account is definitively eliminated. First, the Stonebraker et al. study is the only one to date in which this problem has been addressed. Second, only two subjects were used in the experiment. Third, the results were based on a very limited number of probe trials (20 probe trials of each cue type). Fourth, no statistical analysis was reported, and fifth, performance on FN cued probe trials was superior to that on F cued probe trials. If the cancelling effect of R cues is only the result of conditioning history, then performance on FN cued probe trials should have been similar to performance on F cued probe trials.

The main aim of the present experiment was to determine if the Stonebraker et al. results could be replicated. This would exclude the hypothesis that the control demonstrated by R cues in a double cuing procedure may be the result of the novelty of the situation with two cues. In addition, an attempt was made to determine whether the no cue condition would function as an implicit cue to forget at long delay (5.5-7 sec) intervals. Subjects were provided with training in a no cue condition where the absence of an explicit cue was followed by the omission of the comparison stimuli. The cuing effect was evaluated on three types of single cued probe trials (R, F, and no cue), and two types of double cued probe trials (FR and FN). Double cued probe trials were identical to F cued probe trials in all respects except one: Within the same retention interval, a second cue was presented immediately after the F cue termination. The F cue was followed by an R cue on FR probe trials and by a novel stimulus (a large triangle) on FN probe trials. If the cancelling effect of an R cue is the result of conditioning history and the no cue condition is established as an implicit cue to forget, using long delay intervals, then DMTS accuracy on R and FR probe trials should be approximately equivalent and superior to that on F or no cue probe trials. In addition, if the novelty of presenting two cues in the retention interval does not play a role in determining performance on double cued probe trials, then performance on FN probe trials should be similar to that on F cued probe trials.

METHOD

Subjects and Apparatus. All the subjects and apparatus of the first experiment were employed again. One addition was made. The projectors behind the keys not only displayed the stimuli described in Experiment 1 (red, green, black dot on white background, a horizontal or a vertical line) but also a large triangle onto a frosted rear projection screen.

Procedure. The birds were retrained in a 3 sec choice DMTS task with an identical procedure to that used in Experiment 1. Subsequently, the birds were trained to tolerate progressively longer delays by increasing the retention interval by 1 or .5 sec contingent on criterial performance. Criterial performance to increase the delay interval was defined as at least 80% accuracy on R cued trials for one session. The retention interval was increased .5 sec, if accuracy was between 80% and 84%. If accuracy was above 84%, the retention interval was increased 1 sec. The terminal retention intervals were 7 sec for three of the birds and 5.5 sec for the other two. The mean percent of correct matching responses during the last 3 sessions was 93.17% and 89.38%, respectively. An average of 22.4 training sessions was conducted (range 20-26).

Testing. Twelve testing sessions were conducted. Each testing session consisted of 12 blocks with 12 trials in each block (144 trials). The first 2 blocks of each testing session contained only standard trials (R, F, and no cue trials). Each of the subsequent 10 blocks contained 8 standard trials and 4 probe trials (40 probe trials per session). All standard trials (F, R, and no cue) were identical to those described during training. That is, the comparison stimuli were presented on R cued trials and omitted on F and no cue trials. The cuing effect was evaluated on probe trials. All probe trials contained the comparison stimuli at the end of the retention interval and correct responses were reinforced. Five types of probe trials were used: Remember cued (R), forget cued (F), no cue, forget cue followed by remember cue (FR), and forget cue followed by a novel stimulus (FN, large triangle). Within a testing session, each type of probe trial occurred twice with each of the 4 possible stimulus configurations. The R cued probe trials were identical to standard R cued trials. On F and no cue probe trials, the comparison stimuli were presented at the end of the retention interval. During FR probe trials, a 1 sec remember cue was presented immediately after the F cue offset and the comparison stimuli were presented after the retention interval had elapsed. On FN probe trials, a large triangle was presented for 1 sec on the center key immediately after the F cue termination; the comparison stimuli were presented following the termination of the retention interval.

RESULTS

Separate analyses of variance, using only probe trial data, were performed for percent of correct matching responses and latency of correct responses. The data were analyzed according to type of cue presented (R, F, no cue, FR, or FN) and replication (1, 2, 3, or 4). The twelve testing sessions were averaged across blocks of 3 sessions to obtain the four replications. The rejection level was set at .05 for all the results reported.

Percent of correct matching responses. Figure 4 presents the mean percent of correct matching responses for the last 3 training sessions and for the four replications in the testing phase. The analysis of variance for the probe data indicated a significant effect of cue, _F_ (4, 76)= 3.12. Neither the replication effect, nor the replication by cue interaction were statistically significant (see Appendix E). Table 4 presents the means and standard deviations of correct responses as a function of replications and cues. It will be noticed that the mean percent of correct responses on FR and FN probe trials is identical.

A Tukey's HSD multiple comparison test was performed to determine which means differed significantly. The analysis indicated that performance on F cued probe trials was lower than performance on R cued probe trials. The no cue condition did not differ significantly from either the F or R cue condition. None of the remaining pairwise differences were statistically significant.

Latency of correct responses. The analysis of variance performed on this data revealed no significant main effects or interactions (see Appendix F).

DISCUSSION

Contrary to the evidence indicating that FR cued probe trials lead to a higher DMTS accuracy than FN cued probe trials (Stonebraker et al., 1981), the present results indicated that there was no difference in matching accuracy on FR and FN cued probe trials. This finding does not support the notion advanced by Stonebraker et al. (1981) that an R cue cancels the effect of a previously presented F cue as a result of conditioning history; rather it suggests that the novel presentation of two cues within the retention interval plays a role in determining DMTS performance on double cued probe trials.

A second purpose of the present experiment was to determine whether a no cue condition functioned as an implicit cue to forget at long delays. The analysis indicated that performance on the no cue trials did not differ from performance on either R or F cued probe trials. Accuracy on no cue trials was 2.71% lower than accuracy on R cued probe trials, and 5.84% higher than accuracy on F cued probe trials. Maki et al. (1981) reported that performance on no cue probe trials was significantly lower than that on R cued trials when food samples and long retention intervals were used. In the present experiment, the difference in performance between R and no cue probe trials was not reliable, although the changes in performance were in the same direction than those described by Maki et al. (1981). Moreover, the fact that the present results are comparable to those obtained by Maki et al. (1981) with no food samples and long retention intervals suggests that reliable differences between no cue and R cued conditions can only be obtained with food samples and long retention intervals. However, further research in the area is needed to determine under which conditions performance differences between no cue and R cued probe trials can be obtained.

One important feature of the results in the present experiment was that accuracy on the double cued probe trials as well as on no cue probe trials was not significantly different from performance on R and F cued probe trials. Double cued and no cue probe trials led to an intermediate level of performance with respect to that on R and F cued probe trials. Accuracy on FR and FN cued probe trials was 3.75% higher than that on F cued probe trials, and 4.8% lower than performance on R cued probe trials. Accuracy on no cue probe trials was 2.71% lower than that on R cued probe trials, and 5.84% higher than accuracy on F cued probe trials. To account for this finding it might be argued that the cues were losing their effectiveness to control DMTS performance because 51.84% of the trials ended with the presentation of the comparison stimuli (including R standard trials and all the types of probe trials). In other words, during testing the subjects may have learned to rehearse all sample stimuli, regardless of the type of cue presented since at least 50% of the time, the sample stimulus was followed by the presentation of the comparison stimuli. If this were the case, then a significant effect of replication should have been found. In addition, this hypothesis would suggest an interaction of cue type by replication.

GENERAL DISCUSSION

The main contribution of the present research was the demonstration that neither the omission of the comparison stimuli in a no cue condition nor cuing R and F trials from the outset are sufficient conditions to produce a no cue condition which functions as an implicit forget cue. In Experiment 1, DMTS performance on F cued probe trials was significantly lower than performance on R cued and no cue probe trials. Performance on R cued and no cue probe trials was statistically equivalent in spite of the omission of the comparison stimuli in the no cue trials. Results parallel to those obtained in Experiment 1 were obtained in Experiment 2, despite cuing R and F trials from the start. The evidence suggests that the similarity in performance between R cued and no cue probe trials cannot be explained by arguing that, in Experiment 1, the amount of training provided in the no cue condition was insufficient to establish the no cue condition as an implicit cue to forget, or that in Experiment 2 the subjects learned in one trial that a no cue was always followed by the presentation of the comparison stimuli.

It was mentioned earlier that the only evidence of performance differentiation between no cue probe trials and R cued trials was obtained using long delay intervals and food samples (Maki et al., 1981). One of the aims of Experiment 3 was to investigate the role of long delay intervals in performance on no cue and R cued probe trials. The results, however, were inconclusive. Performance in the no cue condition did not significantly differ from R or F cued probe trials.

In general terms, the evidence obtained in the present research does not support Grant's suggestion that previous training is a critical factor in causing the no cue condition to function as an implicit remember cue.

Furthermore, although performance on double cued probe trials did not differ from that on R or F cued probe trials, accuracy on FR and FN cued probe trials was identical, thereby suggesting that the novel presentation of two cues within the retention interval may be responsible for the effects produced by an R cue in double cuing experiments.

Clearly the decline in DMTS accuracy as a function of the position of the cue cannot be attributed to the fact that the no cue condition was functioning as an implicit cue to forget since performance on R and no cue probe trials was identical. The effects of cue position may be attributable to a general disruption of DMTS performance produced by the novel situation of delaying the cues within the retention interval during probe testing. In Experiment 1, accuracy was significantly higher when the cues were presented in the beginning of the retention interval than when they were presented in the middle or end. In Experiment 2, although the pattern of results was similar to the previous one, the only significant difference was between beginning and end. The reason for this discrepancy is uncertain. Nevertheless, two observations should be made. First, performance was highly accurate in both experiments. As a result of the high accuracy some of the effects of cue position may have been obscured by a ceiling effect. Second, the retention interval may have been too short to allow meaningful differences between the presentation of the cues in the beginning, middle or end of the delay interval.

It was mentioned earlier that the Stonebraker and Rilling (1981) study was conducted to determine whether the decline in performance on F cued probe trials resulted from the fact that the presentation of the comparison stimuli subsequent to F cue was a novel event (i.e., contrary to training) capable of disrupting performance. If this hypothesis were true, delaying the F cue within the retention interval should produce a similar or greater disruption in performance. The results indicated that as the presentation of the F cue was delayed within the retention interval, matching accuracy on F cued probe trials improved to the point of being nearly identical to that on R cued probe trials. In the present research, the directed forgetting effect is also not attributable to the novel presentation of the comparison stimuli on F cued probe trials. Performance on the no cue probe trials was significantly higher than performance on F cued probe trials despite the novel presentation of the comparison stimuli at the end of the no cue probe trials. However, the fact that the directed forgetting effect cannot be attributed to disruption by novelty does not invalidate the possibility that, in the present study, delaying the cues within the retention interval may have produced a general disruption of DMTS performance.

The analysis of latency of correct choice responses as a function of the cue indicated that correct choice responses on F cued probe trials. were made significantly more slowly than on either no cue or R cued probe trials. Furthermore, latencies to select the correct comparison stimulus on no cue probe trials were greater than those on R cued probe trials (Experiment 2). These results may be attributable to the novel presentation of the comparison stimuli following F cues, and the novel presentation of no cue trials during testing, respectively. It was already mentioned that the decline in accuracy on F cued probe trials could not be attributed to the novel presentation of the comparison stimuli during testing. However, it is uncertain whether the presentation of the comparison stimuli during probe testing has an effect on latencies of correct choice responses. Two considerations must be taken into account in evaluating the significance of the latency data. First, the effect of cuing on latencies of correct responses was inconsistent from experiment to experiment. Second, the Maki et al. (1981) study is the only one which provides some evidence that postsample cues have differential effects on overall latencies to select between comparison stimuli on no cue and F cued probe trials. It is apparent that further research is required to determine whether the effect of cuing on latencies of correct responses is a reliable phenomenon.

In general terms, the evidence obtained in the present research suggests that R cues do not exert any functional control over DMTS performance. Nevertheless, the strength of this conclusion is limited. First, in all experiments, overall performance was highly accurate. Hence, a ceiling effect may have obscured differences between the R and no cue conditions. Second, although the effect of cuing on latencies of correct responses was inconsistent from experiment to experiment, postsample cues had differential effects on latencies to select the correct comparison stimulus in Experiment 2. Specifically, latencies to select the correct comparison stimulus on no cue probe trials were longer than those on R cued probe trials. It is not clear how this finding should be interpreted. Third, the results in the double cuing experiment (Experiment 3) were inconclusive. Accuracy on the double cued probe trials and no cue probe trials was not significantly different from that on R and F cued probe trials. The identical performance on FR and FN probe trials may be taken as suggesting that the novel presentation of two cues in the retention interval may be responsible for the effects produced by an R cue in double cuing experiments. However, with the evidence obtained in Experiment 3, it is not possible to determine whether R cues function differently from no cues in double cuing experiments.

The directed forgetting effect in animal subjects has been studied with both a successive DMTS task and a two choice DMTS task. It is interesting to note that the use of a successive DMTS task leads to a larger directed forgetting effect than a two choice DMTS task. The use of different dependent measures in successive and two choice DMTS tasks (i.e., discrimination index and percent of correct responses, respectively) make the comparison between tasks problematic.

A DMTS task consists of two kinds of simple discriminations. First, a successive discrimination between samples on different trials is required (Carter & Eckerman, 1975). Second, depending on whether the task is successive or two choice, the subject must make a successive or a simultaneous discrimination between the comparison stimuli on each trial. Only the implications of the way in which comparison stimuli are presented will be considered. First, in a successive task, responding to the correct stimulus does not preclude responding to the incorrect stimulus. Alternatively, in a two choice DMTS task, responding to the correct stimulus precludes responding to the incorrect stimulus. Second, in a successive task, the decision to respond must be based on a comparison between one stimulus and the memory of the other. By contrast, the selection of the correct stimulus in a two choice DMTS task is made in the presence of both discriminative stimuli. In other words, a two choice DMTS task provides an additional set of relational cues to compare and decide which stimulus is correct, whereas in a successive DMTS task these cues are absent.

If the presence of relational cues increases the probability of making a correct choice, then performance should be more accurate in a two choice DMTS task than in a successive DMTS task. Perhaps, the differences in magnitude of the directed forgetting effect between successive and two choice tasks are the result of successive DMTS task being more difficult than the equivalent two choice DMTS task.

The evidence obtained in the present research is not entirely consistent with any of the main accounts of directed forgetting. The context dependent retrieval hypothesis attributes the directed forgetting effect to a failure to retrieve the memory representation as a result of contextual differences between training and testing conditions. The central assumption of this account is that contextual events present during training acquire control over responding so that these contextual events are necessary to retrieve the required information at the moment of testing.

The results obtained are inconsistent with this hypothesis. Performance on F cued probe trials was significantly lower than performance on R and no cue probe trials. If contextual events acquire control over DMTS performance and those events are necessary to retrieve the memory of the sample at the moment of testing, then performance on the no cue condition should have been similar to performance on F cue trials since both conditions established the context in which the memory of the sample was not usually retrieved. In other words, performance on both no cue and F cued probe trials should have been lower than performance on R cued probe trials since retrieval of the memory of the sample should have only occurred in the appropriate context, that is, the context established by R cues.

In appearance, the decline in DMTS performance as a function of the position of the cue within the retention interval is consistent with the suggestion that the directed forgetting effect is the result of contextual differences between training and testing. If contextual events control performance, then any variation from the original context in which retrieval occurred should produce a disruption of DMTS performance. Recall that, during training, R and F cues were only presented in the beginning of the delay interval whereas during testing these cues were also presented in the middle and end. In addition, the comparison stimuli were omitted on standard no cue and F cued trials, and presented on probe trials. However, if this account were correct, then performance on no cue probe trials should have been equivalent to that on F cued probe trials.

The rehearsal hypothesis assumes that the information extracted from the sample stimulus is maintained in short-term memory by a rehearsal process which occurs throughout the retention interval. Forgetting results when the rehearsal process is interrupted. From this point of view, an R cue maintains rehearsal of the memory of the sample whereas an F cue terminates, or at least reduces, such a process.

Some of the evidence obtained in the present research is not easily explained by the rehearsal account of directed forgetting. Firstly, although performance on F cued probe trials was significantly lower than on R cued probe trials, and this decline in performance is consistent with the assumption that F cues terminate, or at least decrease, rehearsal by signalling either the irrelevance of the sample stimulus or the omission of the comparison stimuli, it is not clear why performance on no cue probe trials was significantly higher than on F cued trials. Since both conditions signalled the same outcome, performance would be expected to be similar. Secondly, for all probe trials (R, F, and no cue), accuracy declined as a function of the temporal position of the cue. In Experiment 1, accuracy was significantly higher when the cues were presented in the beginning of the retention interval than when they were presented in the middle or end, with no significant difference between middle and end, whereas in Experiment 2, the only significant difference was between beginning and end. If it is assumed that F cues terminate or reduce rehearsal because they signal the omission of the comparison stimuli or the irrelevance of the sample, then the no cue may be considered as an F cue since the comparison stimuli were also omitted on no cue trials. Delaying R cues within the retention interval should have decreased matching performance. That is, performance should have been best when R cues were presented in the beginning of the retention interval, and worst when the R cues were presented in the end since in the latter case, subjects spent more time without rehearsing the sample stimulus. Furthermore, delaying F cues within the retention interval should have produced an improvement in DMTS performance. The decrease in accuracy observed on F cued trials is not consistent with the predictions of the rehearsal hypothesis. Furthermore, if the no cue condition was functioning as a forget cue, then performance on no cue probe trials should have been poorer than on R cued probe trials. In addition, no decline in accuracy as a function of the position of the cue on no cue probe trials should have been obtained.

In summary, the present research demonstrated that in a single cuing procedure an R cue did not function differently from a no cue despite the fact that the comparison stimuli were omitted in the no cue condition, or R and F trials cued from the outset. The results do not support the suggestion advanced by Grant (1981) that prior training is responsible for the functioning of the no cue condition as an implicit R cue. With the evidence obtained in the third experiment, it is not possible to support or reject the notion that an R cue cancels the effect of a previously presented F cue as a result of conditioning history. However, the identical performance on FR and FN cued probe trials suggests that the novel presentation of two cues within the retention interval may be responsible for the effects produced by an R cue in double cuing experiments. In addition, evidence that DMTS accuracy declined as a function of the temporal position of the cues was obtained. Perhaps, this outcome was the result of a general disruption in DMTS performance produced by probe testing.

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FOOTNOTES

[1]. Some caution must be taken in evaluating the evidence indicating that the postsample cuing controls orientation towards the key since no formal data have been presented in any directed forgetting experiment. Moreover, Rilling et al. (in press) suggested that the most important difference between R and F cued trials is that R and F cues control different behaviour. However, it is uncertain whether the orientation towards the key is a clear indication that the appropriate context to retrieve the memory of the sample was restored.

[2]. These results have further implications regarding the way in which a directed forgetting experiment may be planned. In a typical directed forgetting experiment with animal subjects, half of the trials are R cued and the other half F cued. However, it is apparent that since R cues do not function differently from a no cue, it would be sufficient for the directed forgetting experiment to cue only F trials.

[3]. Latency of a correct response is defined as the time elapsed between the presentation of the comparison stimuli and the execution of a correct choice response.

4. Tukey's HSD test is indicated for making all a posteriori pairwise comparisons among means. This test sets the experimentwise error rate at α. In order to perform this test the assumptions of normality, homogeneity of variance and random sampling are required. In addition, the number of observations in each treatment level must be equal or approximately equal. See Roger E. Kirk, *Experimental design: Procedures for the behavioral Sciences*. Brooks-Cole, Cal., 1968.

TABLE 1

Mean percent of correct responses as a function of replication, cue and temporal position of the cue for Experiment 1

	REPLICATION				
	1	2	3	4	MEAN
CUE					
R BEG	91.66	94.99	88.33	100.00	93.74
R MID	89.99	76.66	94.99	93.33	88.74
R END	81.66	88.33	88.33	93.33	87.91
MEAN	87.77	86.66	90.55	95.55	
F BEG	84.99	91.66	93.33	93.33	90.82
F MID	78.33	79.99	86.66	91.66	84.16
F END	76.66	86.66	76.66	93.33	83.32
MEAN	79.99	86.10	85.55	92.77	
NO CUE BEG	96.66	94.99	93.33	96.66	95.41
NO CUE MID	88.33	89.99	93.33	94.99	91.66
NO CUE END	86.66	94.99	93.33	93.33	92.07
MEAN	90.55	93.32	93.33	94.99	

BEG: beginning
MID: middle

TABLE 2

Mean percent of correct responses and standard deviations as a function of replication, cue and temporal position of the cue for Experiment 2

REPLICATION	1	2	3	4
MEAN	91.47	92.03	94.99	93.14
S.D.	7.51	8.03	7.44	8.81
CUE	R	F	NO CUE	
MEAN	94.30	89.85	94.57	
S.D.	7.63	10.17	6.03	
POSITION	BEG	MID	END	
MEAN	94.99	93.05	90.68	
S.D.	6.98	7.72	9.14	

S.D.: standard deviation.
BEG: beginning
MID: middle

TABLE 3

Mean latency of correct responses and standard deviations as a function of replication, cue and temporal position of the cue for Experiment 2

REPLICATION	1	2	3	4
MEAN	1.20	1.09	1.13	1.11
S.D.	0.38	0.30	0.37	0.34

CUE	R	F	NO CUE
MEAN	0.96	1.34	1.09
S.D.	0.28	0.40	0.36

POSITION	BEG	MID	END
MEAN	1.15	1.13	1.11
S.D.	0.32	0.37	0.35

S.D.: standard deviation
BEG : beginning
MID : middle

TABLE 4

Mean percent of correct responses and standard deviations
as a function of cue and replication
for Experiment 3

CUE	R	F	NO CUE	FN	FR
MEAN	91.46	82.91	88.75	86.66	86.66
S.D.	7.18	14.61	8.56	9.66	9.83

REPLICATION	1	2	3	4
MEAN	83.82	88.83	87.33	89.16
S.D.	10.36	10.14	11.32	8.14

S.D.: standard deviation

FIGURE 1. Mean percent of correct matching responses. The left panel of the Figure shows DMTS accuracy for the last 3 training sessions. The right panel of the Figure shows DMTS accuracy as a function of cue type and temporal position of the cue.

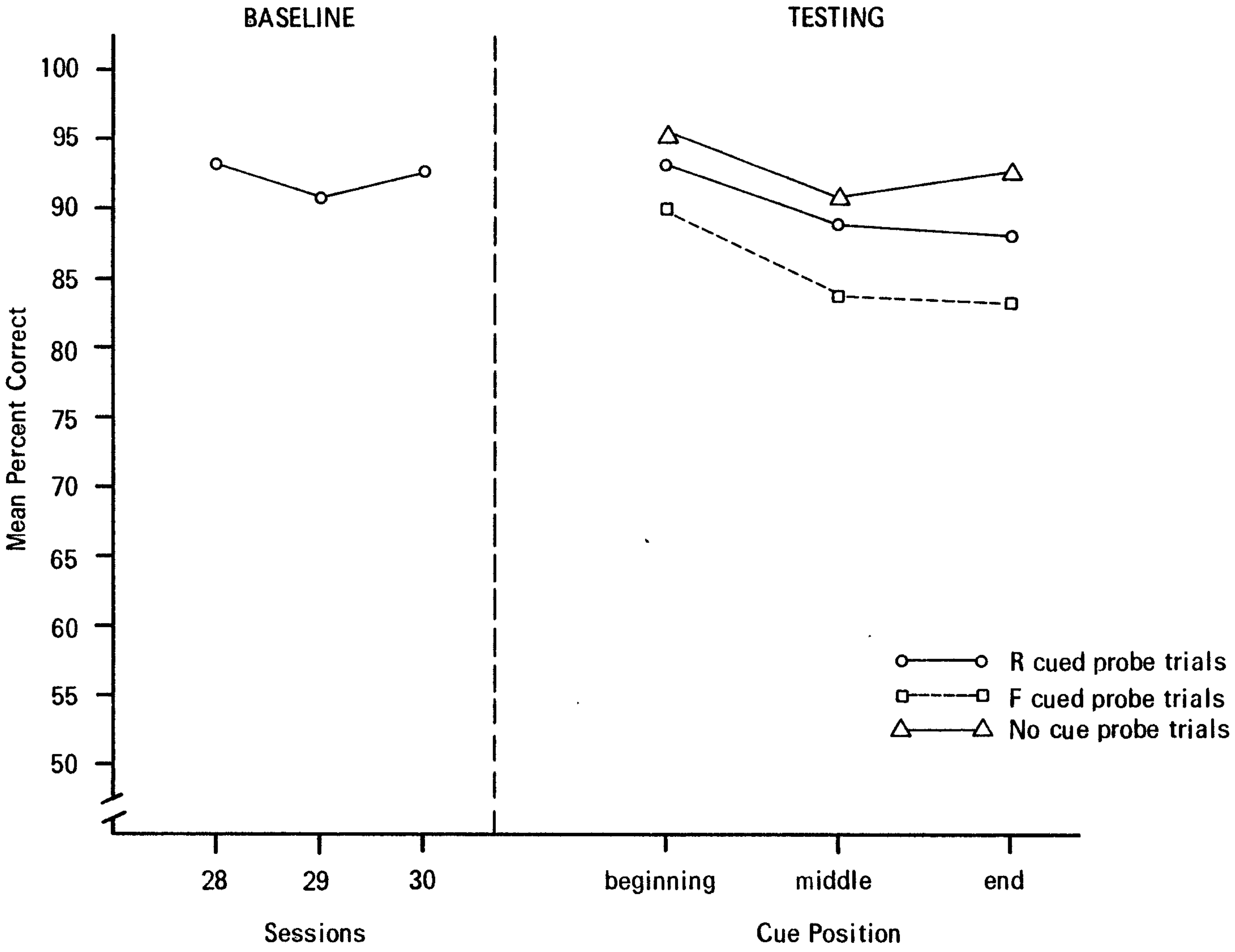

BASELINE
TESTING
Mean Percent Correct
100
95
90
85
80
75
70
65
60
55
50
28
29
30
Sessions
beginning
middle
end
Cue Position
R cued probe trials
F cued probe trials
No cue probe trials

FIGURE 2. Mean percent of correct matching responses. The left panel of the Figure shows DMTS accuracy for R cued trials during the last three training sessions. The right panel shows DMTS accuracy for cues as a function of their temporal position within the retention interval.

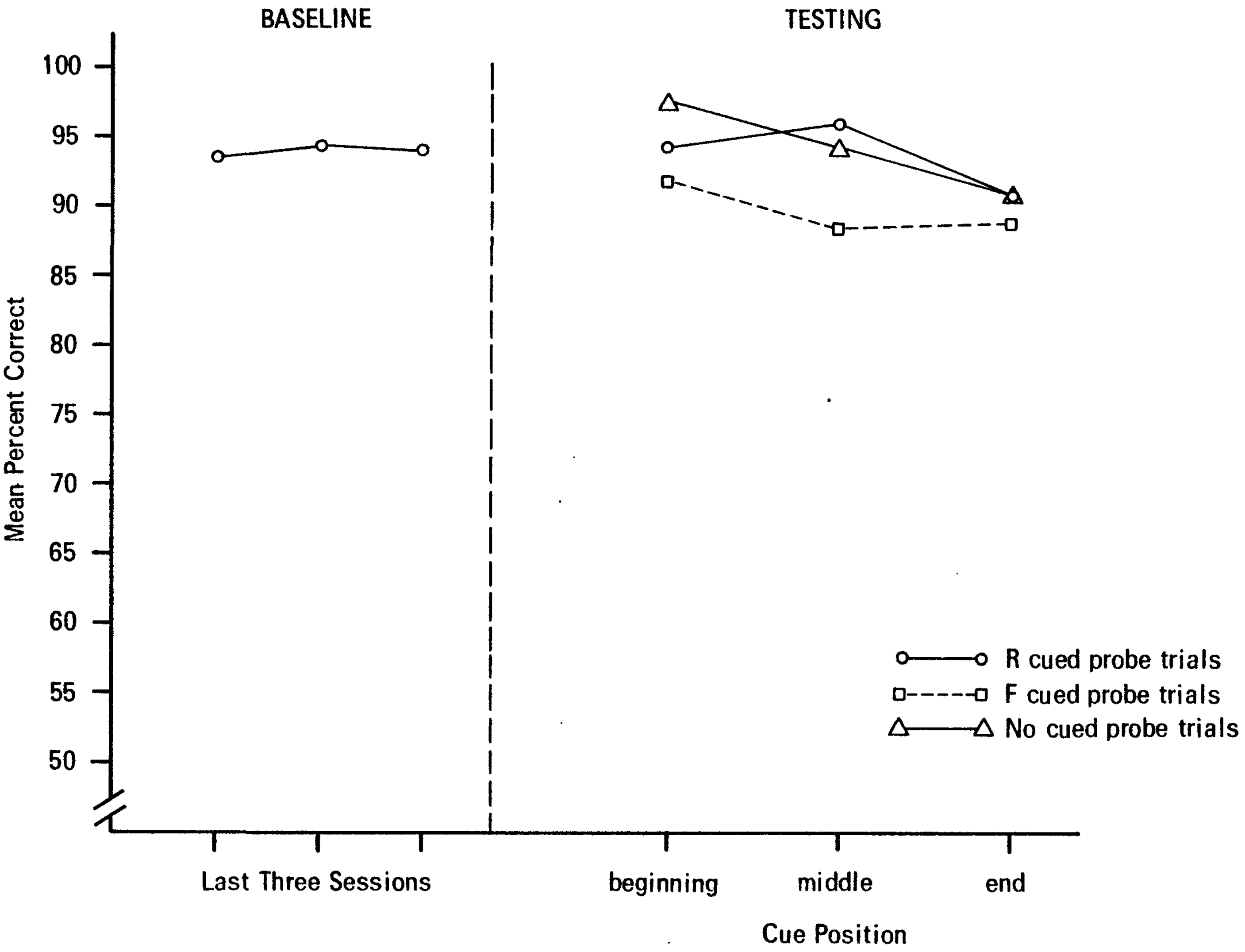

BASELINE
TESTING
Mean Percent Correct
100
95
90
85
80
75
70
65
60
55
50
Last Three Sessions
beginning
middle
end
Cue Position
R cued probe trials
F cued probe trials
No cued probe trials

FIGURE 3. Mean latency of correct responses. The left panel shows the mean latency in sec for R cued trials during the last three training sessions. The right panel shows the mean latency of correct responses for cues as a function of their temporal position within the retention interval.

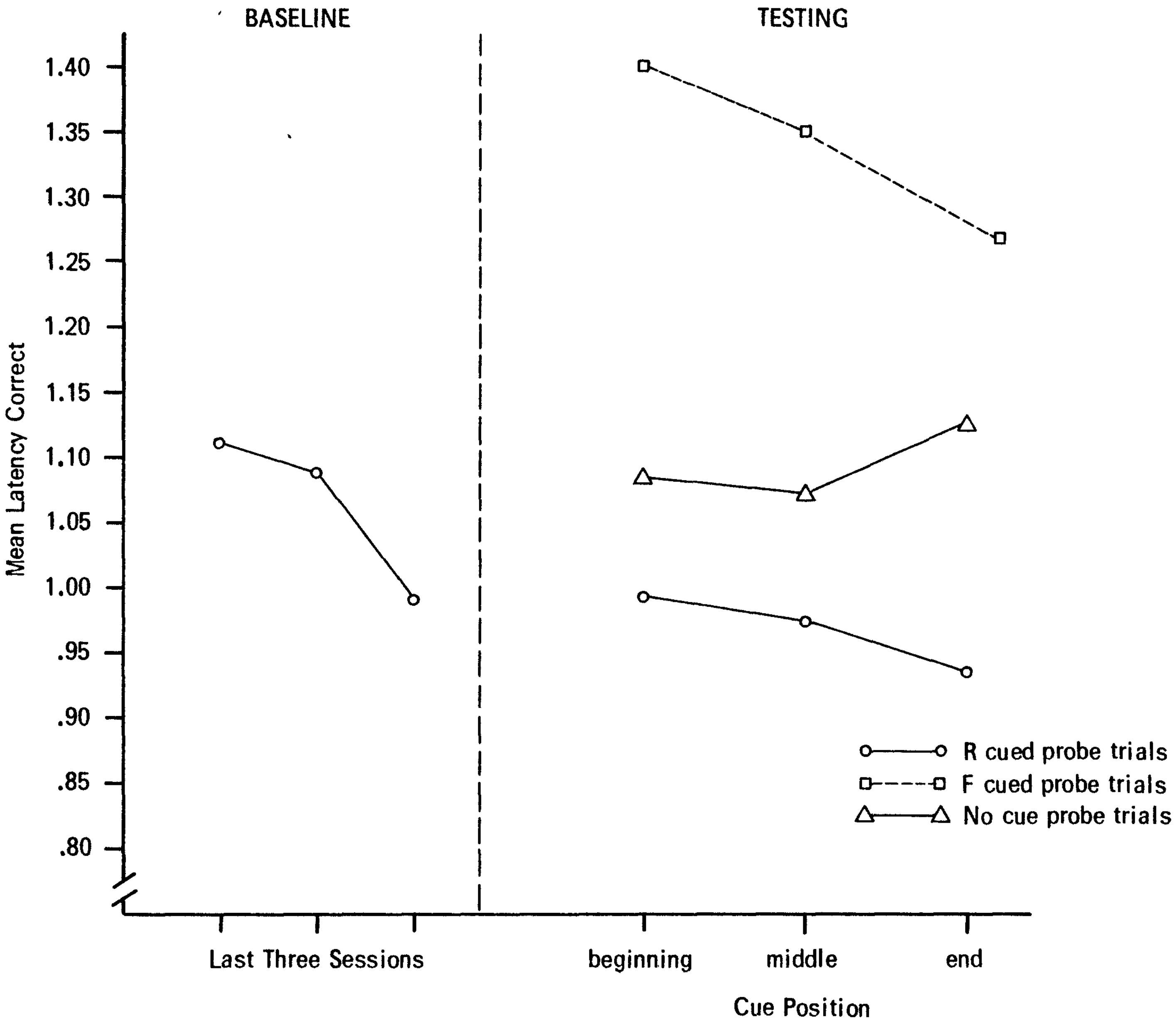
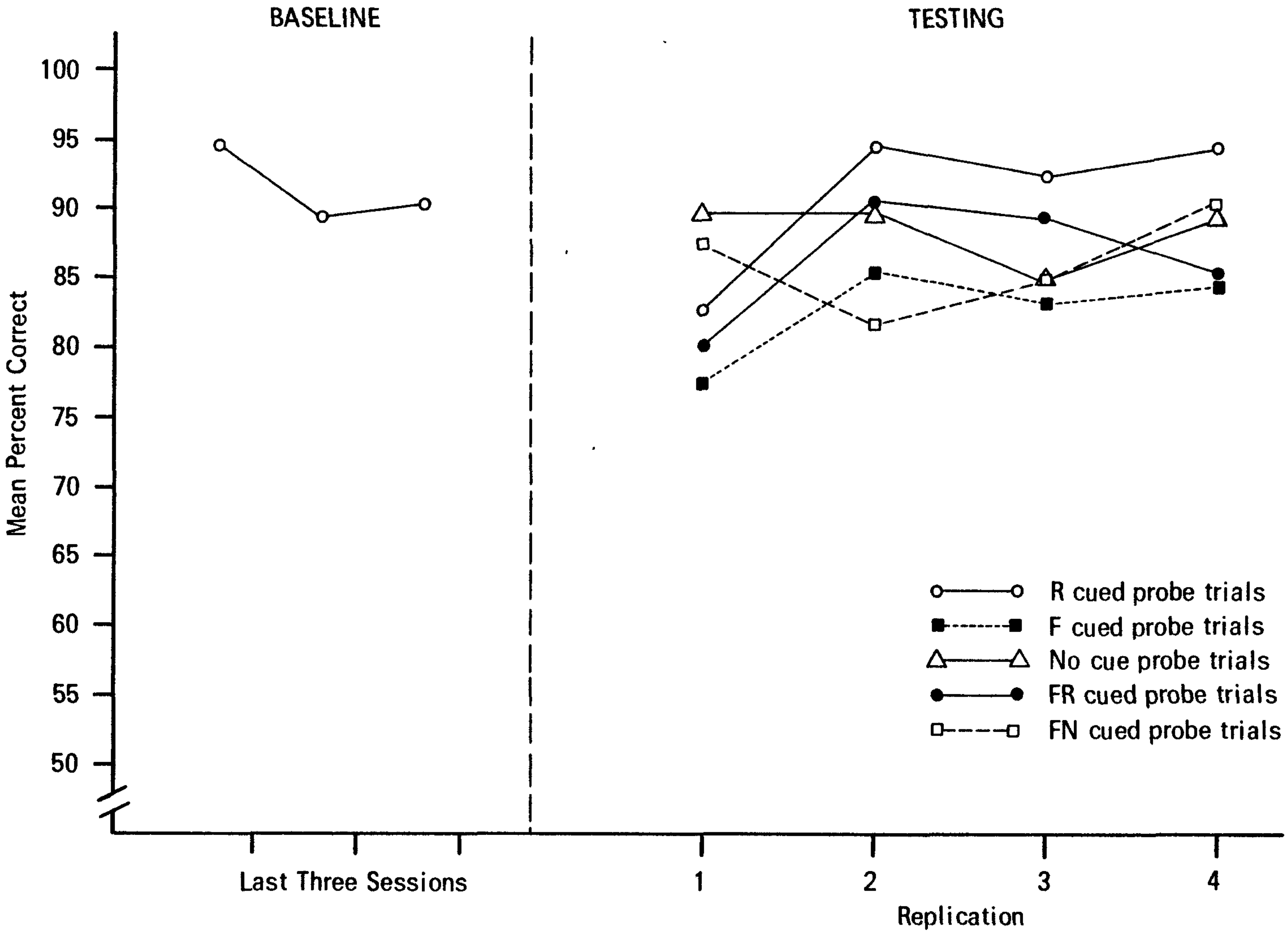

BASELINE
TESTING
Mean Latency Correct
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
.95
.90
.85
.80
Last Three Sessions
beginning
middle
end
Cue Position
R cued probe trials
F cued probe trials
No cue probe trials

FIGURE 4. Mean percent of correct responses. The left panel shows DMTS accuracy for R cued trials during the last three training sessions. The right panel shows DMTS accuracy for R, F, no cue, FN, and FR cued trials as a function of replication.


BASELINE
TESTING
Mean Percent Correct
100
95
90
85
80
75
70
65
60
55
50
Last Three Sessions
1
2
3
4
Replication
R cued probe trials
F cued probe trials
No cue probe trials
FR cued probe trials
FN cued probe trials

APPENDIX A

Analysis of variance for percent correct responses
Summary table for Experiment 1

SOURCE	SUM OF SQUARES	DEGRESS OF FREEDOM	MEAN SQUARE	F
REPLICATION (R)	1637.46	3	545.82	6.69*
CUE (C)	1459.56	2	729.78	8.94*
RC	454.46	6	75.74	0.92
POSITION (P)	1148.98	2	574.49	7.04*
RP	1005.33	6	167.55	2.05
CP	94.07	4	23.51	0.28
RCP	844.37	12	70.36	0.86
ERROR	11416.41	140	81.55	

* $p < .05$.

APPENDIX B

Analysis of variance for latency of correct responding
Summary table for Experiment 1

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
REPLICATION (R)	0.080	3	0.026	1.09
CUE (C)	0.097	2	0.048	2.00
RC	0.085	6	0.014	0.57
POSITION (P)	0.046	2	0.023	0.95
RP	0.100	6	0.016	0.68
CP	0.081	4	0.020	0.83
RCP	0.187	12	0.015	0.63
ERROR	3.424	140	0.024	

* $p < .05$.

APPENDIX C

Analysis of variance for percent correct responses
Summary table for Experiment 2

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
REPLICATION (R)	325.37	3	108.45	1.74
CUE (C)	842.92	2	421.46	6.79*
RC	527.83	6	87.97	1.41
POSITION (P)	558.07	2	279.03	4.50*
RP	497.92	6	82.98	1.33
CP	217.54	4	54.38	0.87
RCP	986.47	12	82.20	1.32
ERROR	8673.23	140	61.95	

* $p < .05$.

APPENDIX D

Analysis of variance for latency of correct responding
Summary table for Experiment 2

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
REPLICATION (R)	0.308	3	0.102	2.74*
CUE (C)	4.366	2	2.183	58.33*
RC	0.252	6	0.042	1.12
POSITION (P)	0.067	2	0.033	0.89
RP	0.321	6	0.053	1.42
CP	0.169	4	0.042	1.13
RCP	0.411	12	0.034	0.91
ERROR	5.240	140	0.037	

* $p < .05$.

APPENDIX E

Analysis of variance for percent correct responses Summary table for Experiment 3

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
REPLICATION (R)	446.47	3	148.82	2.36
CUE (C)	788.37	4	197.09	3.12*
RC	757.48	12	63.12	1.00
ERROR	4786.86	76	62.98	

* $p < .05$.

APPENDIX F

Analysis of variance for latency of correct responding
Summary table for Experiment 3

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F
REPLICATION (R)	0.0847	3	0.028	0.87
CUE (C)	0.1100	4	0.027	0.85
RC	0.1349	12	0.011	0.34
ERROR	2.4568	76	0.032	

* $p < .05$.