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SOURCES OF RETROACTIVE AND PROACTIVE INTERFERENCE IN
CAPUCHIN SHORT-TERM MEMORY

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SOURCES OF RETROACTIVE AND PROACTIVE INTERFERENCE
IN CAPUCHIN SHORT-TERM MEMORY

by

James Lee Lentz

A Dissertation Submitted to the Faculty of the

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In the Graduate College

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As members of the Final Examination Committee, we certify that we have read
the dissertation prepared by James Lee Lentz

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Capuchin Short-Term Memory

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ABSTRACT

The role of various sources of proactive and retroactive interference in the Delayed-Matching-to-Sample (DMTS) performance of five capuchin monkeys (Cebus appella) was examined in a series of four experiments. The DMTS trials were presented in a semi-automated Wisconsin General Test Apparatus (WGTA) with junk objects serving as stimuli.

The first experiment assessed the effects of delay interval (10 or 40 seconds), sample reward (present or absent), and nature of delay interval stimulation (dark or illuminated) on DMTS performance when sample and choice stimuli are drawn from a large pool of stimuli. Performance was better when the sample response was rewarded than when it was not. Correct responding was initially more frequent after dark delays than after illuminated delays; however, with continued training the effects of delay interval illumination disappeared. There was no significant difference in performance with a 10 second and a 40 second delay interval.

The second experiment consisted of two replications of Experiment I: one with the sample and choice stimuli drawn from a large pool (480) of objects and the other with stimuli drawn from a small pool (2) of objects. When stimuli were drawn from the small pool of objects, performance was markedly poorer than

when stimuli were drawn from the large pool. A significant delay interval effect was observed in the small pool task, but as in Experiment I no such effect was observed when stimuli were drawn from a large pool. Performance was poorer on the small pool condition when the delay interval was illuminated than when the houselights were extinguished. However, unlike the effect observed in Experiment I, illuminated delay performance decrements persisted after continued training. No illumination effect was observed for the large pool replication of Experiment II. In both the large and small pool replications, performance was again inferior after nonrewarded sample responses than after rewarded sample responses.

Experiment III was designed to test the hypothesis that animals learn to use delay interval stimuli as cues to remember sample stimuli. After extended training on the small stimulus pool condition with delay intervals illuminated, a number of probe trials were presented. On probe trials, the stimuli previously displayed to the subjects during the delay interval (a yellow and white opaque screen) and the stimuli previously displayed during the intertrial interval (a black opaque screen) were reversed. Contrary to the predictions of the retention-cue hypothesis, DMTS performance was no lower on probe trials than on control trials.

The final experiment was designed to test the hypothesis that emotionally significant events occurring after the sample presentation period can disrupt DMTS performance by displacing

the sample stimulus trace from a limited capacity memory store. In order to insure that the effects of the independent variable not be obscured by floor effect, an intermediate sized (52) pool of objects was used in this experiment. After a pretraining phase, a number of probe trials were presented with a novel sample incentive. As predicted, performance was significantly poorer when the type of incentive was unexpected than when it was expected.

These results were interpreted as evidence that animals are more sensitive to the effects of retroactive interference when proactive interference is high (small stimulus pool) than when it is low (large stimulus pool). It was also suggested that emotional reactions can serve as powerful sources of retroactive interference in DMTS performance. These effects occur regardless of whether the emotional response is negative (sample nonreward) or positive (novel sample reward).

CHAPTER 1

INTRODUCTION

In recent years a great deal of research has been devoted to the study of short-term memory (STM) in animals (Medin, Roberts, and Davis 1976; Honig and James 1971; Medin and Davis 1974; Hulse, Fowler, and Honig 1978). An increasingly popular procedure for studying the processes of animal STM is the delayed-match-to-sample (DMTS) task. A single trial of this procedure consists of a stimulus presentation phase, a retention interval during which the stimulus is no longer present, and a test phase in which the stimulus is presented again but with one or more distractor stimuli. A response to the stimulus which had previously been displayed during the presentation phase (termed the sample) is immediately followed by reward and termination of the trial. Typically, an experimental session consists of a large number of trials with the stimulus serving as sample being randomly selected on each trial.

Presently there are two competing hypotheses to explain forgetting in DMTS. The trace decay hypothesis of Grant and Roberts (1973, 1976) states that when the subject is presented with the sample stimulus, some representation of it is stored in memory. With the passage of time, the quality of this

representation, or trace, is degraded in some way. Errors occur because this decay process renders the memory traces of the sample presented on the current trial and those of previous trials less discriminable.

In contrast, the temporal discrimination hypothesis (D'Amato 1973) states that changes in the quality of memory representations play no role in forgetting. Instead, DMTS errors are interpreted as the consequence of a failure to discriminate which of the choice stimuli has been seen most recently as a sample stimulus.

The present series of experiments was designed to examine a variety of proactive and retroactive sources of errors in the DMTS procedure with complex three dimensional stimuli. Although these studies were not designed to resolve the trace decay versus temporal discrimination controversy, it will be necessary to consider previous research in this theoretical context since this issue has served as the impetus for much of the work on DMTS in animals.

Sources of Retroactive Interference in DMTS

Several manipulations have been imposed on subjects during the retention interval in order to determine the nature of events capable of disrupting the memory trace. One of the first variables suspected of contributing to forgetting was physical activity. Presumably, movement by the animal would damage the memory trace by preventing use of a rehearsal mechanism.

Jarrard and Moise (1970) tested this idea by comparing the performance of stump-tail macaques which were restrained in a primate chair or were free to roam about the test chamber. No differences were found in delayed matching accuracy in these two conditions although response latencies were significantly longer in the nonrestrained condition. The longer latencies in the nonrestrained condition were probably caused by the restrained animals being forced to maintain orientation toward the stimulus panel while unrestrained animals could face away from the manipulanda when the retention interval ended. In another study by Moise (1970), macaques were trained to perform reaction time tasks during the delay interval of DMTS trials. This activity produced significantly poorer performance than a control condition without an interpolated task. Furthermore, while performance decreased as a function of the number of reaction time tasks, the point of interpolation of the task within the retention interval had no effect on performance. The author interpreted this as evidence that the interfering task had no effect on a memory consolidation process. Although it might appear that this experiment demonstrates the disruptive effects of physical activity on retention, it is more plausible that the visually presented reaction time stimuli were the true source of interference. Greater interference from visual rather than motoric aspects of the interpolated task is consistent with research using human subjects which demonstrates greater intramodality than

intermodality interference in recall and recognition tasks (Cohen and Granstrom 1970; Deutsch 1970; and Murray and Neuman 1973).

The evidence for interference in visual DMTS from interpolated auditory simulation is even less convincing than that for interference from physical activity. Neither loud (73dB) white noise nor recorded monkey vocalizations are effective in disrupting delayed matching performance of rhesus macaques (Worsham and D'Amato 1973). This is, of course, also consistent with the assumption of little or no interference between modalities.

Since the information to be remembered on a DMTS trial is typically visual (at least when pigeons and monkeys serve as subjects), it follows that interpolated visual stimulation should serve as a more effective source of retroactive interference than stimulation in other modalities. Two types of visual interference have been studied: interference produced by interpolation of stimuli drawn from the pool of potential choice stimuli and interference produced by nonspecific stimuli bearing no clear relationship to potential choice items.

In a study of the first type, Jarvik, Goldfarb, and Carley (1969) presented rhesus macaques with negative, positive, or neutral stimuli during the delay intervals of DMTS trials. Negative stimuli were found to severely disrupt performance while positive stimuli facilitated performance relative to that obtained with a control condition. Neutral stimuli had no effect on performance. Zentall (1973) trained pigeons on a DMTS task in which the sample and comparison stimulus differed only in hue.

These animals were then treated for interference with an interpolated novel wavelength or shape presented on the sample key.

Both types of interpolated stimuli resulted in poorer performance than a control condition without an interpolated stimulus. However, the most interesting finding was that more interference was produced by the novel wavelength than by the novel shape.

This finding of greater intradimensional disruption than extradimensional is not always obtained. In another study with pigeon subjects, Grant and Roberts (1976) found no difference in interference effects when the interpolated stimuli were from the same or different stimulus dimension as the choice stimuli. Similarity among the sample, interpolated, and negative comparison stimulus when all were drawn from the same stimulus dimension did seem to be important, however. Only two choice stimuli (red and green response keys) were used in this experiment. When the sample was green, a yellow interpolated stimulus presented on the sample key produced strong retroactive interference. Similarly, when the sample was red, a blue interpolated stimulus produced interference. In contrast, facilitation was observed when a green sample was followed by a blue stimulus and when a red sample was followed by a yellow stimulus. Grant and Roberts presented these findings as evidence that pigeons base their choice responses on the stimulus most recently seen (i.e., the interpolated stimulus) and that wavelength generalization from the interpolated stimulus to either the correct or incorrect comparison items produces the observed facilitative and disruptive effects.

A recent series of studies by Medin, Reynolds, and Parkinson (1980) using macaque monkeys as subjects demonstrated that re-presentation of the sample stimulus is more effective in facilitating performance than is interpolation of a stimulus which matches the sample stimulus on the relevant stimulus dimension but differs on some irrelevant dimension. In addition, performance was facilitated when the outcomes of responses to the sample and interpolated stimuli were the same (reward or non-reward). When the outcomes of responses to sample and interpolated stimuli differed, performance was disrupted. This effect was found to be greater when the sample and interpolated stimulus matched on an irrelevant dimension than when they did not. Media et al. (1980) argued that this pattern of results is inconsistent with Grant and Roberts (1976) hypothesis that sample and interpolated stimuli are encoded separately and decay independently. If the independent trace decay position is correct, retroactive interference is a consequence of generalization from the interpolated stimulus to the negative choice stimulus. Yet, the finding that an interpolated stimulus matching the sample on an irrelevant dimension will disrupt performance when the outcomes of the sample and interpolated stimulus differ, seems to indicate that sample and interpolated stimulus encodings interact. If this interaction occurs, retroactive interference is the result of the interpolated stimulus altering the memory representation of the sample. The facilitative effects of interpolated stimuli which match the sample on either relevant or irrelevant dimensions were

ascribed by Medin et al. (1980) to a retrieval-cue property of the interpolated stimulus. The re-presentation of this common dimension thus serves as a cue to trigger recall of the sample trace, effectively reducing the delay interval.

In a study focusing on a slightly different issue, Reynolds and Medin (1979) compared DMTS performance of macaque monkeys when the negative choice stimulus was interpolated (condition A⁺B), when a neutral stimulus was interpolated (condition RI), when the sample was preceded by a neutral stimulus (condition PI), and when no distractor preceded the sample or was interpolated between the sample and choice presentations (control condition). Although performance on the RI and PI conditions did not differ, performance on the A⁺B condition was significantly lower than these two conditions and the control conditions. Furthermore, whereas performance on the RI and PI conditions was significantly above chance, performance on condition A⁺B was significantly below chance. In a subsequent experiment, the same group of subjects was given 360 additional trials on condition A⁺B, yet performance remained below chance. Reynolds and Medin argued that poor performance on this condition was consistent with the trace decay hypothesis, asserting that this hypothesis implies that the response rule, "choose the stimulus matching the stronger trace" is learned more easily than the response rule "choose the stimulus matching the weaker trace." They also argued that the temporal discrimination hypothesis predicts that responding to the least recently seen stimulus should be learned

as easily as responding to the most recently seen stimulus. If time is considered to be a physical attribute similar to size or length, then it should not matter whether a response is directed toward a stimulus associated with small quantities (recently seen) or with larger quantities (less recently seen) of that attribute. However, it is not clear why the temporal discrimination hypothesis could not incorporate a response bias for the most recently seen stimulus just as the trace decay hypothesis incorporates a response bias for the stimulus with the strongest memory trace. In fact, a temporal discrimination hypothesis incorporating such a recency bias could explain the results obtained as well as the trace decay hypothesis. Two of the conditions (RI and A^+B) involved interpolation of a stimulus between the sample and choice presentations; yet, in the RI condition the interpolated stimulus did not reappear on the choice test. Thus the A^+B condition was the only one in which the most recently seen choice object was not correct. The fact that the A^+B condition produced performance significantly below chance may merely reflect that the animals had not yet overcome a bias to respond to the most recently seen stimulus. Such a bias would no doubt be strengthened by concurrent training on the other conditions.

A major difficulty with studies of this type is that one can never be certain that the subject interprets the contingencies arranged by the experimenter in the manner intended. Thus the experimenter may define the "sample stimulus" as the stimulus

which is presented immediately after the intertrial interval and the "interpolated stimulus" as any stimulus which is presented during the retention interval. He may expect that the animal learns the rule, "respond to the choice object seen previously as sample." However, the animal may not interpret the task in this manner. Instead it might learn the rules, "if there is a single stimulus respond to it; if there are two stimuli respond to the most recently seen one." Note that the animal is "defining" sample (stimulus most recently seen) differently than the experimenter (stimulus presented at the beginning of a trial). In control conditions where trials consist only of a single sample stimulus followed by a choice presentation, application of either of these two rules will lead to a correct response. Yet, when the incorrect comparison object is presented between the experimenter-defined sample and choice presentations application of these rules will lead to different outcomes. An "ideal" animal using the experimenter's rule will choose the correct stimulus but an animal using the recency rule will choose the incorrect choice object. This interpretation suggests that performance decrements occurring when the negative comparison stimulus is interpolated are not due to interference or forgetting but are instead a consequence of the inability of the experimenter to communicate precisely the desired task to the subject.

Zentall (1973) proposed that when stimuli differing from both the positive and negative choice items are interpolated, the instruction confusion hypothesis can be ruled out. Although

Zentall found retroactive effects by interpolating non-comparison stimuli on the sample key, similar studies (Grant and Roberts 1976; Jarvik et al. 1969; Medin et al. 1980) have failed to replicate this result without some degree of similarity or association between the sample and interpolated stimulus or between the negative comparison and interpolated stimulus. Perhaps the most unambiguous case for retroactive interference is provided by the experiments of Medin et al. (1980) in which the outcome of an interpolated stimulus differed from the sample, and the sample and interpolated stimulus were related on an irrelevant dimension.

Interpolation of nonspecific visual stimuli which cannot be confused as sample and choice items would seem to avoid this problem. One such type of nonspecific stimulus can be provided by altering the ambient illumination during the delay interval. It has long been known that delayed-response performance is superior when the animal spends the delay interval with the house lights off as opposed to on (Malmo 1942; McDowell and Brown 1960). Similar results have been obtained with the DMTS task using both primate (D'Amato and O'Neill 1971; Etkin 1972) and pigeon (Grant and Roberts 1976; Maki, Moe, and Bierley 1977; Roberts and Grant 1978; Maki 1979a) subjects. Herman (1975) demonstrated that dolphins performing an auditory DMTS task make fewer correct responses when noise is presented during the delay interval than when the interval is spent in silence.

A commonly observed characteristic of the houselight effect is that the amount of illumination during the delay interval

is inversely related to performance. In pigeons the intensity of delay interval illumination has produced this effect (Grant and Roberts 1976) while similar results have been obtained with capuchin monkeys by manipulating the duration of delay interval illumination (Etkin 1972).

Since many models of both animal (Medin and Davis 1974) and human (Waugh and Norman 1965) memory assert that the probability of an item leaving short-term storage and entering long-term storage is an increasing function of the time the item is held in short-term storage, it would therefore seem that the point of interpolation within the delay interval should exert a strong effect on performance. However, no point of interpolation effects have been observed in primates (Moise 1970; Etkin 1972) and curiously, pigeons perform more poorly when illumination is introduced late in the delay interval (Roberts and Grant 1978).

Over the years, a number of explanations for this phenomenon have been advanced. Hypotheses suggesting differences in activity during illuminated and dark delays are most certainly incorrect. Etkin (1972) demonstrated that capuchin monkeys are no more active in the light than in the dark and that activity preceding correct and incorrect DMTS trials does not differ. Further evidence is provided by the study of Jarrard and Moise (1970) which found no difference in the matching performance of physically restrained and unrestrained monkeys.

Both trace decay and temporal discrimination interpretations of the houselight effect have also been advanced.

D'Amato (1973) incorporated the houselight effect into his temporal discrimination hypothesis by suggesting that intervals spent in the dark are subjectively briefer. Presumably this would occur because the lack of changes in visual stimulation while in the dark would make it difficult for the animal to judge the passage of time. The trace decay hypothesis holds that illuminated delays disrupt performance because the continuous processing of visual information during the delay interval acts to degrade the trace of the sample stimulus held in a visual short-term store (Grant and Roberts 1976; Roberts and Grant 1978). As mentioned above, Roberts and Grant (1978) found that with pigeon subjects, interpolated illumination is more disruptive when it occurs at the end of the delay interval than when it occurs at the beginning. This somewhat counterintuitive finding was interpreted as evidence that delay interval illumination disrupts only weak memory traces such as those degraded by the passage of time.

A number of recent papers suggest that both the trace decay and temporal discrimination hypotheses provide inadequate explanations of the houselight effect. Instead, it may be that non-illuminated delay facilitation is an artifact of the training procedures typically conducted in pigeon and primate operant chambers. In such procedures a response to the sample display is programmed to extinguish the houselight and initiate the delay interval. Illuminated delay intervals are therefore significant deviations from the sequence of events the animal has become familiar with. Tranberg and Rilling (1980) trained pigeons on

four variations of a successive DMTS procedure: houselight on during both delay and intertrial intervals, houselight on during intertrial intervals and off during delay intervals, houselight off during intertrial intervals and on during delay intervals, and houselight off during both delay and intertrial intervals. After training the birds on these four conditions, each group was switched to a condition in which the houselight status during the delay period was inverted. In all cases, whether the delay interval changed from dark to light or light to dark, performance dropped relative to baseline levels. Maki, Olson, and Rego (1979) obtained similar results by giving their birds extended training with illuminated delays after initial training with dark delays. Although the houselights were initially disruptive, matching performance gradually recovered. Extended training on the illuminated delay condition led to decrements in performance when dark delays were re-established. A second study showed that delay interval changes are most disruptive when they occur at the end of the delay period. Finally, Cook (1980) initially trained pigeons to match with illuminated delay intervals. Subsequent imposition of dark delays once again was found to disrupt DMTS performance. In a fashion similar to the original houselight effect, delay interval darkening was increasingly disruptive as the duration of the darkened period increased and as the intensity level decreased.

Since the houselight effect is clearly not a simple consequence of ambient illumination during the delay interval it is

now important to determine why changes in delay interval stimulation disrupt DMTS performance. Maki et al. (1979) suggested that delay interval stimuli are subject to the effects of reinforcement and combine with the sample trace to control matching performance.

Tranberg and Rilling (1980) examined a number of potential explanations of the phenomenon. One interpretation states that a change in delay interval stimulation from that experienced on previous trials is surprising. Because the new delay interval stimuli are unexpected they capture the animal's attention and consequently displace the sample trace from a limited capacity short-term store. If this were the case the animal would be expected to recover from the change as it habituated to the surprising effects of the new delay interval stimuli. Yet, when an animal does recover from delay interval stimuli changes, it does so very slowly (Shimp and Moffit 1977). It seems unlikely that the "new" delay interval stimuli would still be surprising after several hundred trials. Three other hypotheses were found to be more plausible.

If pigeons use sample-specific mediating behaviors (Zentall et al. 1978) to bridge the delay, these behaviors could eventually become conditioned to the delay interval stimuli. Subsequent changes in delay interval stimuli would break this overt mediation chain and thus depress matching performance. A similar interpretation stated in cognitive terms follows from Spear's (1973) retrieval deficit hypothesis. This explanation is

based on the assumption that delay interval stimuli serve as contextual retrieval cues. Changes in these stimuli could cause forgetting by either eliminating retrieval cues or by causing the retrieval of competing memories.

Finally, delay interval stimuli could come to serve as an "instruction" to remember the sample stimulus (Honig 1978). When delay interval stimuli are changed, performance drops because the animal can no longer discriminate the intertrial interval (when it should forget) from the delay interval (when it should remember). There is little reason at this point to prefer one of these explanations of the delay stimulation change effects to the others.

Reinforcement Effects in Immediate Memory Tasks

Another variable which could exert retroactive effects on DMTS performance is sample stimulus reinforcement. Although at first glance it might appear that rewarding responses to the sample stimulus will always lead to superior performance, evidence exists that reward can sometimes lead to poorer performance than nonreward. Unfortunately, the effects of sample reward on DMTS performing has been the subject of little research. However, a large body of research exists on reinforcement effects on discrimination learning set (DLS) formation, an experimental paradigm which bears many similarities to the DMTS task.

In a typical DLS experiment, a subject is presented with a pair of stimulus objects on each trial and responses to one of

the objects are consistently rewarded. In fixed-problem methods, the same pair of objects is presented for some set number of trials with distinct object-pairs defining different problems. Depending on the species under investigation and the amount of prior experience, the number of trials per problem may range from 2 (Hayes, Thompson, and Hayes 1953) to 50 or more (Rumbaugh and Prim 1964; Tyrell in Warren 1965). The phenomenon of interest in DLS studies is that as a subject is exposed to increasing numbers of problems, the rate at which it learns to respond to the correct object in a single problem increases. Note that on the first trial of a problem the probability of a correct response will always be 0.5 since no prior information is provided about the outcome of responding to either object. With practice, correct performance on trial-2 should increase if the animal is able to use the trial-1 outcome as a cue for future choices.

The typical finding in comparing performance of macaque monkeys after trial-1 reward and nonreward is that subjects perform better after trial-1 nonreward than trial-1 reward. This somewhat surprising finding is often referred to as the Moss-Harlow (1947) effect. This phenomenon is characteristic of experienced subjects, with naive animals usually performing better after trial-1 reward (Warren 1966). However, studies in which two stimuli are presented on trial-1 of each problem are difficult to interpret since the effect of trial-1 reward or nonreward on trial-2 performance of a problem may be confounded with stimulus preferences (Bessemer and Stollnitz 1971; Medin 1972). If

stimulus preferences do occur it will be impossible to determine whether the subject responded to the previously rewarded object because it remembered the object and the reward associated with it or because it simply has a preference for the object which is incidentally associated with reward.

In order to separately measure the effects of trial-1 reward and stimulus preferences, a number of researchers have compared performance on trial-2 after a single object is presented on trial-1 (e.g., Moss and Harlow 1947; Fletcher and Cross 1964; Boyer 1966). Note that when the trial-1 object is rewarded, the first two trials of this task are quite similar to a single DMTS trial. With only one object available on the first trial, the possibility of stimulus preferences interacting with trial-1 outcomes is eliminated. In studies of this type with macaque monkeys, trial-1 nonreward leads to better performance on subsequent trials than trial-1 reward regardless of the level of experience of the subjects (Medin 1972).

Unfortunately, interpretation of this finding is clouded by two potential sources of confounding. In the typical adaptation procedure used in DLS studies, monkeys are trained to displace single objects from the center foodwell. A consequence of this adaptation procedure is that subjects may learn to ignore objects singly presented on the center foodwell since they do not predict future rewards. Generalization from this procedure to trial-1 single object studies could therefore account for poorer performance on trial-1 reward problems than might otherwise be

expected. In addition, a tendency to respond to novel objects could simultaneously lower trial-1 rewarded performance and increase trial-1 nonrewarded performance (Medin 1972).

The response rule acquired in a typical learning set study can be characterized by the term "win-stay, lose-shift for the object" since the animal must repeat responses to rewarded objects and change responses after responding to a nonrewarded object. A series of studies (McDowell and Brown 1963a, 1963b; McDowell, Gaylord, and Brown 1965; and Brown, McDowell, and Gaylord 1965) entailed comparison of performance of monkeys on two-trial DLS problems in which different groups of animals were required to repeat responses to rewarded objects (win-stay), change responses after an initial nonrewarded choice (lose-shift), change responses after an initial rewarded choice (win-shift), and repeat a response to an initially nonrewarded choice (lose-stay). Although all of these response rules could be learned, lose-stay was acquired the most readily and surprisingly, win-stay was acquired least readily. The superiority of lose-stay over win-stay shows some degree of species generality, occurring in rhesus macaques (McDowell et al. 1965), stump-tail macaques (Brown et al. 1965), and baboons (Brown et al. 1965). This effect also occurs in both discrimination learning experienced (McDowell et al. 1965) and naive (Brown et al. 1965) subjects.

These findings support the view that reward of the trial-1 object functions more as an informative cue than as an

automatic reinforcer. A group of studies by Riopelle (1955; Riopelle, Francisco, and Ades 1954; Riopelle and Francisco 1955) have shown that this informative function can be performed by a nonconsumable object such as a marble. Interestingly, a marble under the correct trial-1 object supports a higher level of trial-2 performance than food. The inferior performance obtained with food-reward conditions is generally attributed to distracting properties of the food (Riopelle 1955; Medin 1977). Distraction caused by food-reward could operate in two ways. After displacing the object, the subject's attention could be diverted toward the reinforcer, terminating further processing of the stimulus qualities of the object. This explanation of the performance decrement proposed that performance is poorer because the stimulus is not adequately encoded. The second explanation of food-cue disruption instead asserts that processing of the stimulus always ceases as soon as it is pushed back by the subject, regardless of the contents of the foodwell. The cue (food, marble, or empty foodwell) is then effectively a second stimulus which is input into short-term storage along with a representation of the stimulus object. Since food-reward is very likely a more emotionally significant event than marble-reward (or possibly nonreward), sight of the food could act to lower performance by displacing the trial-1 or sample stimulus from short-term memory.

Sources of Proactive Interference in DMTS

Just as events occurring after the presentation of the sample may disrupt matching performance, events prior to the sample presentation may also be effective sources of interference. A useful way of organizing the research on proactive interference in DMTS is to classify studies on the basis of whether the source of interference acts between or within trials.

One effective intertrial variable in DMTS performance is the length of the intertrial interval (ITI). While increasing the delay interval acts to decrease performance, increasing the ITI generally acts to improve performance on DMTS tasks.

When the stimuli consist of spatial positions (i.e., the spatial delayed-response task) the effects of varying ITI are somewhat uncertain. Gleitman et al. (1963) found that when delayed-response trials were massed (20 per day), the performance of their rhesus monkey subjects was inferior to that obtained when only two trials per day were presented. However, Fletcher and Davis (1965) found no difference in the delayed-response performance of rhesus monkeys with 8-, 16-, and 24-second ITIs. The reason for this discrepancy is not known but it is likely the differences in the magnitude of the ITIs in the two studies were responsible. In any event, the causes of ITI effects on delayed-response performance are difficult to determine since it is not always possible to rule out delay mediation through spatial orientation in this task. Because physical orientation can be used to bridge delay intervals, proactive effects could be the

consequence of maintained physical orientation to the position last responded to, as well as competing memory traces (Lentz and King in press). If this is the case, long ITIs would facilitate performance by increasing the likelihood that when each trial begins the animal would no longer be oriented toward the position last chosen.

Since spatial orientation as a means of bridging the delay interval is unlikely in nonspatial DMTS tasks, an effect of ITI variation on color or form delayed matching performance is more readily interpreted as the consequence of changes in some memory process. In addition to being easier to interpret, nonspatial DMTS ITI effects seem to be more consistently obtained than spatial DMTS ITI effects. Brief ITIs produce poorer performance than long ITIs in nonspatial DMTS across a wide variety of species and procedural variations. Jarrard and Moise (1971) presented stump-tail macaques with DMTS trials at 5-, 15-, 30-, and 60-second intervals. The shortest ITI produced significantly poorer performance than the other intervals. Herman (1975) obtained similar results using a single bottle-nosed dolphin subject on an auditory DMTS task with poorer performance at ITIs of 15 seconds or less as opposed to 30 seconds or more. Maki et al. (1977) found that short ITIs produced poorer performance in pigeons when the stimuli being matched were either colors or occurrences of reinforcement (food or no food). Roberts (1980) presented pigeons with random DMTS trials (either of the two possible choice stimuli are presented as sample in a random fashion

across trials) and homogeneous DMTS trials (only one of the choice stimuli occurs as sample in a given block of trials) at 1- and 20-second ITIs. Surprisingly, performance was poorer with the brief ITI in both conditions. Finally, Nelson and Wasserman (1978) examined the effects of ITI on successive match to sample performance in pigeons. In this study, the retention task consists of the presentation of a single stimulus. If the stimulus matches the immediately preceding sample, a keypeck will be rewarded. If the test stimulus differs from the sample, a keypeck will result in a blackout period with no reinforcement. With this procedure, the discrimination index (response rate on matching trials/response rate on all trials X 100%) was found to increase as ITI increased.

Both the temporal discrimination by the ITI thesis and the trace decay hypothesis are supported by the ITI effect. According to the temporal discrimination hypothesis, long ITIs improve performance by making presentation times of successive sample stimuli more discriminable (D'Amato 1973; Worksham 1975; Moise 1976). The trace decay hypothesis incorporates the ITI effect by stating that long delays permit greater decay of stimulus traces from previous trials. If traces from previous trials are very weak relative to the current sample trace, there is little competition between them (Grant 1975; Roberts and Grant 1976).

However, the finding of Roberts (1980) that short ITIs also yield poorer performance on homogeneous DMTS trials does not seem to support either hypothesis. According to the temporal

discrimination hypothesis, ITI should, at worst, have no effect on homogeneous DMTS trials since the comparison stimulus which is correct within a block of trials does not change. The temporal discriminations to be made here are between the time the correct choice stimulus was last presented as sample and the time the incorrect choice stimulus was last presented as sample. On homogeneous trials, the incorrect choice stimulus had never been presented as sample so the time since last sample presentation can be considered infinitely long. In contrast, the time since last presentation for the correct stimulus in this experiment ranged from 6 to 18 seconds (ignoring response latencies). Since the incorrect choice stimulus never occurs as sample, decreasing the ITI should have no effect--the temporal discriminations will be between a stimulus seen from 6 to 18 seconds ago and a stimulus never seen as sample.

According to the trace decay hypothesis, short ITIs should facilitate performance on homogeneous DMTS trials. Since only one comparison stimulus ever occurs as sample, each sample presentation should increment the trace strength of that stimulus. If sample presentations occur closer in time to each other, there should be less time for the resultant trace from each to decay and therefore increments in the trace strength of the correct stimulus should be greater when the ITI is short.

Roberts (1980) interpreted the superior performance attained with a long ITI on homogeneous DMTS trials by suggesting that the massed presentation of trials containing the same

information results in an attenuation of processing of the sample stimulus. When trials are distributed or trials containing novel information are introduced, less attenuation of sample processing will occur. Evidence for this suggestion is provided by Roberts (1980, Experiment IV). In this experiment, a group of DMTS trials with matching stimuli on a different dimension was embedded in a block of homogeneous DMTS trials. In this condition performance was superior with short ITIs as would be expected if attenuation of sample stimulus processing were reduced or eliminated.

Another intertrial variable which results in proactive interference is the size of the set of potential stimuli from which the sample and choice stimuli are drawn. In most DMTS experiments only two stimuli are available to serve as sample and negative choice stimulus. With one exception, studies of stimulus pool size have shown that performance increases with the size of the stimulus pool. Varying the set of potential stimuli from two to four items, Etkin and D'Amato (1969) found no effect with their capuchin monkey subjects. This negative result is undoubtedly the result of a very restricted range of stimulus pool sizes. Worsham (1975) found that the matching performance of his capuchin monkey subjects increased with stimulus set size at long delay intervals when set sizes of two, three, and seven were compared. Mishkin and Delacour (1975) compared the performance of test-naive rhesus monkeys at both matching and non-matching to sample with stimuli drawn from pools of two or 200 junk objects.

Non-matching to sample with a large pool of stimuli was acquired most rapidly, reaching a 90% correct over 40 trials criterion in 200 trials. Matching to a sample drawn from the large pool was acquired next most rapidly with the criterion being reached in 400 trials. Neither of the two groups using stimuli drawn from a pool of two objects reached the criterion in 1,000 trials. The difference between matching and non-matching groups probably reflects an unlearned preference for responding to novel objects, since the initial performance of the matching from a large set group was initially below chance (40% correct over 40 trials).

Similar results have been obtained by Sands and Wright (1980) using a serial probe recognition task (SPR). In the SPR task the subject is first presented with a list of stimuli, in this case color slide projections of ordinary objects. After the subject has seen the entire list, a series of probe trials is presented. On a probe trial, a single stimulus is presented to the subject. If this stimulus was in the list, the subject is rewarded for making a "yes" response (moving a response lever to the right). If the probe was not in the list, the subject must make a "no" response (moving the response lever to the left) in order to receive reinforcement. Probe recognition performances of a human and a rhesus monkey on this task were compared for 3-item lists with stimuli drawn from either a 211-item pool or a 6-item pool. With both subjects, performance was poorest with lists drawn from the 6-item pool. The monkey averaged 93% correct with the 211-item pool and 70% correct for the 6-item pool

while the human averaged 96% correct with the 211-item pool and 89% correct with the 6-item pool.

The finding of large stimulus pool superiority in matching performance is again consistent with both of the major theoretical interpretations of DMTS. According to the temporal discrimination view, when sample stimuli are drawn from a large pool of items, it is very unlikely that the negative comparison stimulus will have been seen as sample recently. The temporal discrimination to be made, therefore, will be between a stimulus seen as sample only a few seconds ago and a stimulus which may not have been seen for days. In contrast, when only two stimuli are available to serve as stimuli, the probability is quite high that the negative comparison stimulus will have been presented as sample on the preceding trial. In the second case, the difference between time last seen as sample of the choice stimuli will, of course, be much less than in the first case and discrimination performance will consequently be much poorer (D'Amato 1973; Worsham 1975).

The trace decay position argues that large stimulus pool performance is superior because the negative comparison stimulus has most likely not been presented as sample for many trials and the memory trace of that stimulus must therefore be weak relative to the trace of the correct (sample) comparison stimulus. If both comparison stimuli have been seen on immediately preceding trials, as is the case when the stimulus pool is small, the trace strength of both stimuli will be relatively high and competition

between these traces for control of the choice response will lower performance (Roberts and Grant 1974, 1976).

Roberts (1980) has suggested that factors other than temporal discriminability and differences in trace strength may contribute to the superiority of matching to samples drawn from a large pool. In the experiment described above, in which homogeneous DMTS trials from a new stimulus dimension were embedded in control homogeneous DMTS trials, performance on embedded trials was superior to that obtained on control trials. Roberts suggested that the novel sample stimuli may have received additional processing over the familiar control stimuli and hence were more memorable. He also proposed that a similar mechanism facilitates delayed matching with large stimulus pools. When sample stimuli are drawn from pools of a few hundred items, each stimulus remains somewhat novel and will consequently receive a relatively large amount of processing. When only two stimuli are used, both become quite familiar and receive less attention when presented as sample.

Still other mechanisms may contribute to the differences in performance observed with large and small stimulus pools. Herman (1975) suggested that different types of memory may be measured in the two types of DMTS tasks. When only two stimuli are used, permanent and relatively complete memory representations of both stimuli develop as training proceeds. If representations of both stimuli are more or less complete, then temporal factors will serve as stronger cues in controlling performance. Yet when

a very large number of complex stimuli are used, performance may be a function of the completeness of the memory representation of the sample stimulus at choice time. In DMTS with a very restricted stimulus pool, the question to be answered at choice time is "which stimulus was seen more recently?" but with very large stimulus pools, the question becomes "which choice stimulus was (ever) seen?" Forgetting in small stimulus pool DMTS thus reflects failure of a discrimination process while in large stimulus pool DMTS it is the consequence of the loss of attributes of a stimulus representation in memory. Another related possibility is that small stimulus pool DMTS is mediated by the rehearsal of something similar to an "instruction" (cf. Honig 1978) while large stimulus pool DMTS is the function of a gradually eroding memory representation. The instruction (e.g., "depress the green key") would be formed at sample presentation time and executed at choice time.

Proactive effects occurring across trials have also been studied by arranging "hard" and "easy" sequences of DMTS trials. Worsham (1975) tested cebus monkeys on DMTS trials with stimuli drawn from a pool of nine items. Two types of sequences were composed. Hard sequences were arranged so that the negative choice stimulus on trial n almost always occurred as the correct (i.e., sample) stimulus on trial $n-1$. "Easy" sequences were constructed such that the negative stimulus on trial n had not occurred as sample for at least three preceding trials. As expected, performance was significantly poorer on hard sequences.

The author interpreted this as evidence for failure of a temporal discrimination.

In a somewhat more elaborate series of experiments, Grant (1975) examined the performance of pigeons on the second trial of 2-trial DMTS sequences in which the roles of the correct and incorrect choice stimuli on trial-2 were reversed from trial-1 (i.e., the correct stimulus on trial-1 was incorrect on trial-2). In the first experiment, trial-2 performance was compared when trial-1 was presented one, four, or six times. A single presentation of trial-1 had no effect on zero-second delay trial-2 performance but longer delays produced evidence for retrieval deficits. When trial-1 was presented four or six times, performance decrements were observed at all delays, including zero-seconds. This seems to indicate that a single preceding trial with correct and incorrect choice stimuli reversed from the current trial acts to impair retrieval but multiple presentations of such a trial impair both processing and retrieval of the sample stimulus. In a second experiment the trial-1 presentations consisted of only the choice phase of the DMTS trial (i.e., no sample was presented). The control condition in this experiment consisted of a single DMTS trial without the interfering trial-1 presentation. No difference was found between the control task and experimental conditions in which the negative stimulus on trial-1 was the same as on trial-2 or when the negative stimulus on trial-1 was not presented on trial-2. However, performance was again impaired relative to the control condition when the

roles of trial-1 choice stimuli were reversed on trial-2. The author interpreted these results as evidence that the occurrence of a preceding trial per se does not impair performance and that the observed proactive effects with single trial-1 presentations are the consequence of a retrieval deficit not just an encoding deficit. Finally, trial-2 performance was examined when separated from a single proactive trial-1 by ITIs of 2, 20, and 40 seconds. Proactive interference was produced only with the briefest ITI. Grant interpreted this body of results as evidence for a trace decay process in which stimulus traces from the current and preceding trial are encoded separately and decay independently. Proactive interference in this model is the result of competition between traces of nearly equal strength for control of the choice response.

Another means of assessing inter-trial proactive effects is to determine the relative frequencies of trial n outcomes (or responses) as a function of trial $n-1$ response, outcome, or correct choice stimulus. This method has the advantage of avoiding the construction of stimulus sequences with systematic patterns (e.g., the alternating of correct choice stimuli in Grant (1975)). Moise (1976) examined the trial n performance of pigtail macaques as a function of trial $n-1$ response position, sample stimulus, and outcome. When the trial $n-1$ correct response position differed from the trial n correct response position, performance was significantly poorer than when the two correct response positions were the same; however, this difference only occurred at

zero-second delay interval. A change of sample stimuli on successive trials resulted in significantly poorer performance at all delays (0, 1, 5, 10, and 20 seconds) than when the same stimulus served as sample on adjacent trials. Finally, when the same stimulus served as sample on successive trials and the trial n-1 choice was correct, performance on trial n was superior to that obtained when the trial n-1 choice was incorrect. The opposite trend was observed when the sample stimuli were different on successive trials. A similar interaction between outcome and sequence of sample stimuli was observed in random DMTS trials with pigeon subjects (Roberts 1980). When response position sequences were examined, this interaction occurred in homogeneous DMTS trials but not in random DMTS trials. The author interpreted the existence of sequence by trial n-1 outcome interactions as evidence that the stimulus or position responded to on trial n-1 is retained over the ITI and interferes with the correct choice on trial n but that the previous trial's outcome is quickly forgotten. This is consistent with the finding of similar response perseveration in delayed-responding (Lentz and King in press) and may indicate that proactive interference from the previous response position occurs only when short-term memory of the visual characteristics of the sample is not crucial to the choice response. In delayed-response only the position of the stimulus need be recalled and in homogeneous DMTS only long-term storage of the sample is necessary. Random DMTS performance instead requires that the visual qualities of the sample are

retained and a limited capacity short-term store may insure that previous response positions as well as outcomes are quickly forgotten.

The other major method for studying proactive interference is to place the proactive event within trials. In studies of this type, two sample stimuli are presented in succession prior to the delay interval. The first stimulus, S1, may or may not appear as the negative choice stimulus after the delay. The second stimulus, S2, is the true sample stimulus and is always rewarded when presented at choice time.

In an early study of this type, Jarvik et al. (1969) found performance decrements in their rhesus monkey subjects when the negative choice stimulus (S1) was presented prior to the sample (S2). This effect occurred only when the interval between the two samples (the interstimulus interval or ISI) was eight seconds or less. Grant and Roberts (1973, Experiment I) varied the delay interval with S1 and S2 presented in immediate succession. Although this proactive condition did produce significantly poorer performance in their pigeon subjects than a control condition, faster forgetting was not observed. It was therefore concluded that S1 produced a general performance decrement rather than increased forgetting. In another experiment Grant and Roberts (1973, Experiment II) orthogonally varied delay interval (0 or 3 seconds), ISI (0 or 10 seconds), S1 schedule (FR1 or FR30), and S2 schedule (FR1 or FR5) in an attempt to test various predictions of the trace decay theory by manipulating the

strengths of the hypothetical traces of the comparison stimuli. The results provided some support for the theory. The short ISI produced significantly poorer performance as did the higher rate of S1 responding. Both of these manipulations could easily be interpreted as acting to make the trace strengths of S1 and S2 more similar at choice time. Yet, increasing the S2 schedule from FR1 to FR5 did not have the predicted effect of reducing interference from S1. It is, however, possible that if the animals were required to make even more responses to the S2 stimulus, a statistically reliable effect would have been produced.

Just as the use of multiple sample stimuli as a means of studying retroactive interference is subject to interpretations involving the confusion of task instructions rather than enhanced forgetting, similar problems exist in using this method to study proactive interference. Zentall and Hogan (1974, Experiment I) attempted to eliminate this possibility by presenting an S1 which did not occur as either the correct or incorrect choice item. Although their single pigeon subject did display significantly poorer performance on the proactive task in the first five 96-trial test sessions, differences between the control and experimental conditions soon disappeared. In contrast to the findings of Grant and Roberts (1973) of parallel forgetting functions, in the first five sessions a significant interaction was observed between delay interval and presence of the S1 stimulus. This interaction would seem to indicate faster forgetting when a neutral stimulus is presented prior to the sample. However, in

a subsequent study, Zentall and Hogan (1977) concluded that this interaction was an artifact of a ceiling effect for the control condition.

If a nonchoice stimulus can produce significant proactive effects, as this study seems to suggest, the magnitude of the effect must be very slight. In a similar experiment, Grant and Roberts (1973, Experiment III) varied the ratio of S1 responses from FR1 to FR30 when S1 did not occur as a choice stimulus. Yet even with the high response ratio, performance was no different than that obtained on a control condition in which no S1 preceded the sample. This result was interpreted by the authors as evidence that the proactive effects of earlier studies were the consequence of competition between memory traces rather than an S2 encoding deficit caused by the S1 presentation. Reynolds and Medin (1979) also found no difference in the performance of their monkeys on a proactive condition using a single sample stimulus. The results of this study must, however, be treated with caution since the within subjects design may have created task confusion between concurrently presented retroactive, proactive, and control conditions.

Summary

Certain types of stimulation, when presented either before (proactive) or after (retroactive) an item to be remembered, can disrupt performance relative to that on retention tests without such interfering stimuli. Studies of retroactive

interference in the DMTS procedure can be categorized on the basis of whether the interpolated stimulus is a potential choice item or an event which does not resemble sample or comparison items. The most popular type of non-choice item stimulation has involved changes in the level of illumination present in the test chamber, although studies of discrimination learning set performance suggest that reward events could also serve as a source of retroactive interference.

Studies of proactive interference can be categorized on the basis of whether the source of the interference occurs within or between trials. Intratrial studies of proactive interference involve the presentation of a potential choice item prior to the sample stimulus presentation. Intertrial proactive interference studies show the effects of previous trials on performance caused by (a) varying the ITI, (b) varying the number of stimulus items which may serve as sample and choice stimuli, and (c) varying the reward value (positive or negative) of a choice stimulus between successive trials.

Studies of interference in the DMTS task have produced a number of important empirical findings. When potential choice items are used as interfering stimuli, the greatest proactive and retroactive interference occurs when these stimuli vary along the same stimulus dimension as the sample but differ in particular values; however, the use of potential choice items as interfering stimuli often creates difficulty in interpreting the source of performance decrements.

The temporal location of an interfering event is important when such an event occurs before and possibly after the sample stimulus. Proactively interfering stimulation becomes more disruptive as the interval between the interfering stimulus and the sample decreases. The effects of the temporal locus of proactive stimulation are somewhat unclear with some studies revealing no effect and at least one study revealing greater effects when interpolated stimulation occurs near the end of the delay interval.

Many studies using both the delayed-response and DMTS tasks seemed to indicate that retention was poorer after illuminated delay intervals than after dark delay intervals. Recent evidence, however, suggests that illumination per se does not disrupt performance but that the cause of these effects is a change in illumination relative to a baseline level.

Studies of intertrial proactive interference have indicated greater interference when (a) the ITI is short rather than long, (b) the number of potential sample and choice stimuli is small rather than large, and (c) the reward value of choice stimuli on adjacent trials is reversed rather than held constant. Examinations of the effects of trial n-1 events upon trial n have revealed that when only two stimuli are available as sample and choice items, memories of the position responded to and the object responded to but not the outcome on the immediately preceding trial may interfere with performance.

Both of the major theoretical approaches to forgetting in DMTS, the trace delay and temporal discrimination hypotheses, seem to be able to account for most of the empirical findings of studies of interference. Perhaps if these hypotheses were stated in a more precise and formal manner, their relative merits could be more easily assessed.

CHAPTER 2

PURPOSE

Very restricted stimulus sets have been used in most DMTS studies; often such a set will consist of only two items. Herman (1975) has suggested that different memory mechanisms may be responsible for DMTS performance with large and small stimulus sets. When small sets are used, each item is seen frequently and the subject consequently develops relatively permanent memory representations of all stimuli. Since all items are represented in memory at choice time, the animal must base its response on the relative recency of the comparison objects. In contrast, with large stimulus set DMTS, each item will remain relatively novel since it is rarely seen by the subject. If all stimuli are somewhat unfamiliar, the integrity of a stimulus representation may play a more important role in performance than recency. In view of the potentially different mechanisms involved in these two types of DMTS procedures, it is important that the variables known to affect small stimulus set DMTS also be examined in large stimulus set DMTS.

In the few studies of large set DMTS to date (e.g., Mishkin and Delacour 1975; Reynolds and Medin 1979), the apparatus and procedure have been quite different from those used in

small set DMTS. Researchers studying small set DMTS typically use simple, one or two dimensional stimuli projected onto keys in an operant chamber. In contrast, experiments with large stimulus sets are almost always conducted in a Wisconsin General Test Apparatus (WGTA) with complex multidimensional junk objects as stimuli. Another potentially important difference is that in small set studies, attention to the sample is usually enforced by the requirement of a nonreinforced response to the key upon which it is projected. This response terminates projection of the sample and initiates the delay interval. However, in large set DMTS studies with the WGTA, subjects either displace sample objects for food reward (e.g., Mishkin and Delacour 1975) or observe placement of rewards under sample objects (Hayes and Thompson 1953). Since trial-1 reward is known to exert strong effects in discrimination learning set performance, its role in both large and small set DMTS should be understood.

The present study's major purpose was to compare the effects of delay interval stimulation, delay interval duration, and sample reward in large and small stimulus set DMTS. While the first two experiments of this study were underway, results became public (Maki et al. 1979; Cook 1980; Tranberg and Rilling 1980) which challenged traditional interpretations of the interfering effects of delay interval stimulation. In view of these findings and the results of the first two experiments, the final two experiments of this study were designed to test specific hypotheses

about performance decrements caused by changes in delay interval stimulation.

CHAPTER 3

EXPERIMENT I

The first experiment was designed to investigate the effects of delay interval stimulation, delay interval duration, and sample stimulus reward upon DMTS performance with a large stimulus set. Delay interval stimulation was manipulated by testing the animals either with houselights out or with houselights on during the delay period. In order to prevent observation of a reward being placed under the correct choice objects during illuminated delays, an opaque screen was lowered at the onset of the retention period.

The use of such a mechanism to obscure the stimulus tray and choice items during the delay can potentially create problems. Motiff, DeKock, and Davis (1969) found that the delayed-response performance of monkeys is disrupted if an opaque screen is lowered after the pre-delay cue. Since no such disruption occurred if a different screen, introduced from the side of the apparatus, was used to obscure the stimulus tray during the delay period, Motiff et al. argued that disruptive effects in delayed-responding will occur only if stimuli present during the delay interval (when the animal should remember a spatial position) do not differ from stimuli present during the intertrial interval

(when the animal should forget a spatial position). In order to prevent a similar effect in the current DMTS experiment, two distinct screens were used so that the animal could discriminate the ITI from the retention interval.

Method

Subjects

Three male and three female feral-born, adult capuchin monkeys (Cebus apella) were subjects. These animals were experienced with object discrimination and delayed-response tasks prior to the first experiment. All were fed a full day's ration after the last test session of the day and were maintained at 90-93% of their ad lib weight. Difficulties were encountered in recording data obtained from one female subject. Since the accuracy of this animal's protocols could not be guaranteed, this animal's data were not included in the statistical analysis of the results.

Apparatus

The monkeys were tested in a darkened room with white noise provided to mask external noises. Testing was performed in a modified Wisconsin General Test Apparatus (WGTA) with two motorized sliding opaque screens. The screen nearest the subject was painted black, and measured 30.5 cm x 35.0 cm and was used to delimit trials. The other screen was positioned directly behind the first screen and measured 20.0 cm x 35.0 cm. The side

of the screen which faced the subject was painted with yellow and white diagonal stripes, 2.5 cm wide. This screen was used to obscure the stimulus tray during illuminated delay intervals and was painted distinctively in order to aid the subject in discriminating the beginning of a delay interval from the end of a trial (when the black screen is lowered).

The stimulus tray, painted black, measured 16.0 cm x 35.0 cm and was equipped with three sets of tracks for holding stimulus objects. These tracks were positioned 8.5 cm apart, center to center. The middle track was used to present sample objects and the outer two tracks were used to present comparison objects. To insure an adequate view of flat stimulus objects, the tray was angled 15 degrees from horizontal.

The stimulus tray and opaque screens were illuminated by two 25 watt incandescent bulbs mounted on either side of the subject's holding cage. With the exception of dark delay trials, these lights remained on throughout testing. On dark delay trials, they were extinguished upon delay onset and relit upon completion of the delay interval.

The stimuli were 576 junk objects which were painted a variety of colors and were mounted on 4.0 cm x 4.0 cm x 0.5 cm wooden squares.

Testing Procedure

Since the subjects were all experienced with displacing junk objects from a formboard in a WGTA, no prior adaptation was

necessary. The sequence of events in a typical trial were as follows. First, both doors were raised to reveal the sample object in the center track. After the subject displaced the object, the delay interval screen was lowered to obscure the animal's view of the stimulus tray (in dark delay trials the houselights were extinguished so that the screen would not be visible to the subject). During the delay interval the experimenter moved the sample object to an outer track, placed a reinforcer (one-quarter miniature marshmallow) under it, and positioned a comparison object in the other outside track. At the end of the delay interval the screen was raised, and the subject was allowed to respond to one of the objects. Both doors were then lowered and a 20-second ITI followed. A different pair of junk objects was used on each trial with the status of sample being randomly assigned. After every 12 test sessions the stimulus objects were re-paired at random.

The subjects were tested under each of the following four conditions: rewarded sample--dark delay (R-D), rewarded sample--lighted delay (R-L), nonrewarded sample--dark delay (NR-D), and nonrewarded sample--lighted delay (NR-L). Each of these conditions were presented with 10- and 40-second delay intervals. On dark delay conditions the side lights were extinguished with the lowering of the screen at the onset of the delay and were restored as the door was raised at the end of the delay. During light-delay conditions, the side-houselights remained on throughout the trial, so that the subject was presented with the yellow

and white door during the delay interval. On rewarded sample trials a reinforcer was placed under the sample object during both the sample presentation and choice phases. In nonrewarded sample conditions the correct choice object was rewarded only when presented in the choice phase (i.e., no reward was given when the same object was presented as the sample stimulus). Since the object seen as sample was rewarded in the choice phase of both sample reward conditions, the predelay reward of the sample was irrelevant to the correct solution of a given trial.

The reward x illumination conditions were presented in 3-trial problem blocks, arranged so that nonrewarded sample problem blocks were always followed by rewarded sample problem blocks and visa versa. All variables except position of correct choice object remained constant within these 3-trial problem blocks. The delay interval illumination conditions were ordered haphazardly over test sessions. Each daily test session consisted of 24 trials or eight 3-trial problem blocks. Two problem blocks of each of the four reward x illumination conditions were presented in each test session. A single delay interval was used in a given test session and the duration of the delay interval alternated from day to day. Two hundred forty trials of each delay x reward x illumination condition were presented.

The rewarded position on each trial was determined by a complex sequence composed so that each of the eight possible 3-trial right-left sequences occurred equally often in a daily test

session and in each of the delay x reward x illumination conditions.

Results

The percentage of correct responses was analyzed with a four factor (Blocks x Delay x Illumination x Reward), within subjects analysis of variance (ANOVA). Overall performance increased significantly ($F(4,16)=19.08$, $p<.001$) over 192-trial blocks. Mean percentage correct over the first block was 67.8; by the last block the animals were averaging 83.5% correct. Performance was slightly but significantly superior ($F(1,4)=31.58$, $p<.005$) when the delay interval was spent in the dark (78.6% correct) as opposed to the light (75.0% correct). The animals also performed better when the sample was rewarded (80.6% correct) than when it was not rewarded (73.0% correct) ($F(1,4)=21.34$, $p<.01$). Surprisingly, delay had no effect ($F(1,4)=3.04$, $p>.05$). Mean performance on 10-second delay conditions (77.9% correct) averaged only slightly better than on 40-second delay conditions (75.7% correct).

Although performance on illuminated conditions was initially poorer than that observed on dark conditions, it improved more rapidly in the first two blocks resulting in a significant interaction between blocks and illumination ($F(4,16)=6.64$, $p<.002$). There was essentially no difference in performance on the two illumination conditions over the last three blocks (see Figure 1).

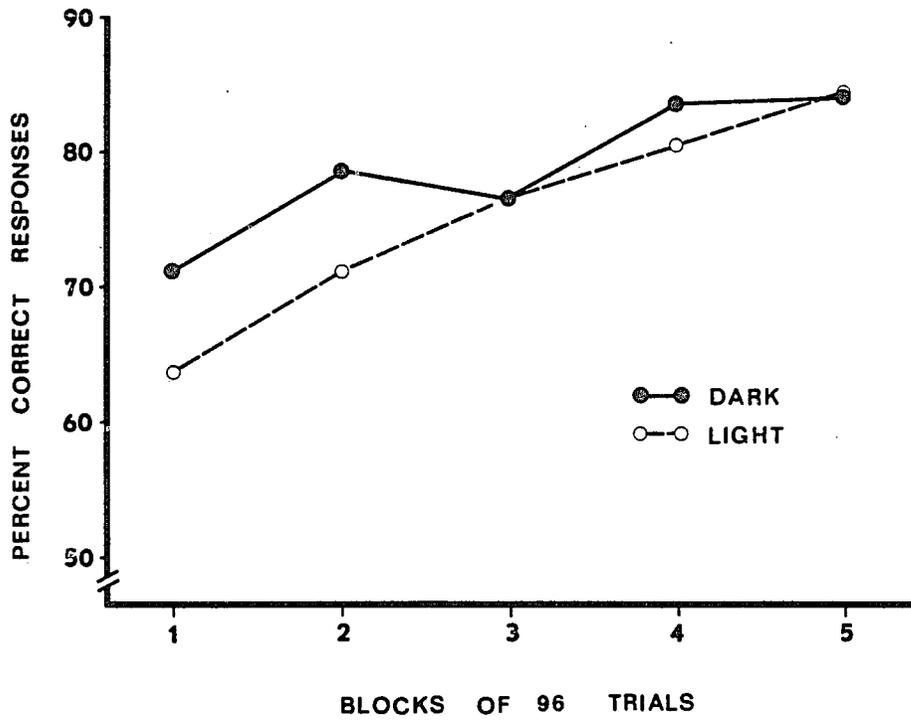


Figure 1. Mean Percent Correct Responses as a Function of Delay Interval Illumination

A different pattern was observed when performance was compared on the two reward conditions over blocks. Figure 2 reveals essentially parallel learning curves with rewarded conditions maintaining a constant superior performance overall five blocks. The interaction between blocks and reward was not significant ($F(4,16)=1.12$, $p > .05$) nor was the interaction between delay interval and blocks ($F(4,16)=0.31$, $p > .05$).

A significant interaction between delay and reward was also observed ($F(1,4)=7.96$, $p > .05$). Although performance with 10-second delay intervals was similar on rewarded and nonrewarded sample conditions (80.5% and 75.3% correct, respectively), a relatively large difference was observed with 40-second delay intervals (see Figure 3). Thus it appears that increasing the delay had no effect when the sample was rewarded but did decrease performance when the sample was not rewarded.

Discussion

The initially high overall performance (67.8% correct over the first 192 trials) obtained in this experiment is consistent with the results obtained by Mishkin and Delacour (1975) with rhesus monkeys on large stimulus set DMTS. Unfortunately, since the subjects used in the present study were not experimentally naive, one cannot rule out contributions of positive transfer from previous experiments in discrimination learning.

In contrast to the rapid forgetting functions observed in small stimulus set DMTS (e.g., Jarrard and Moise 1971; Roberts

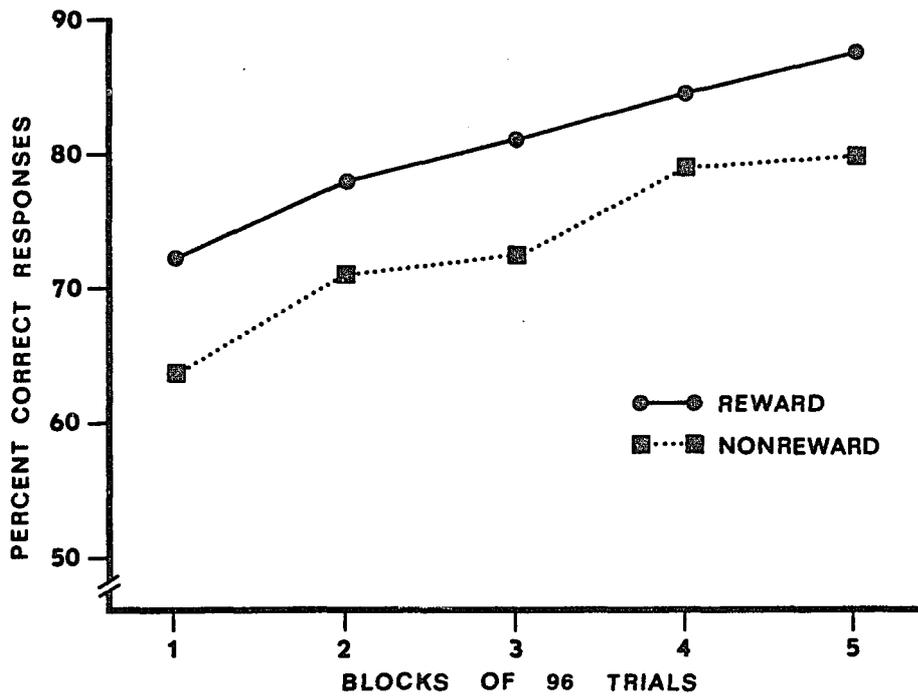


Figure 2. Mean Percent Correct Responses as a Function of Sample Reward Condition

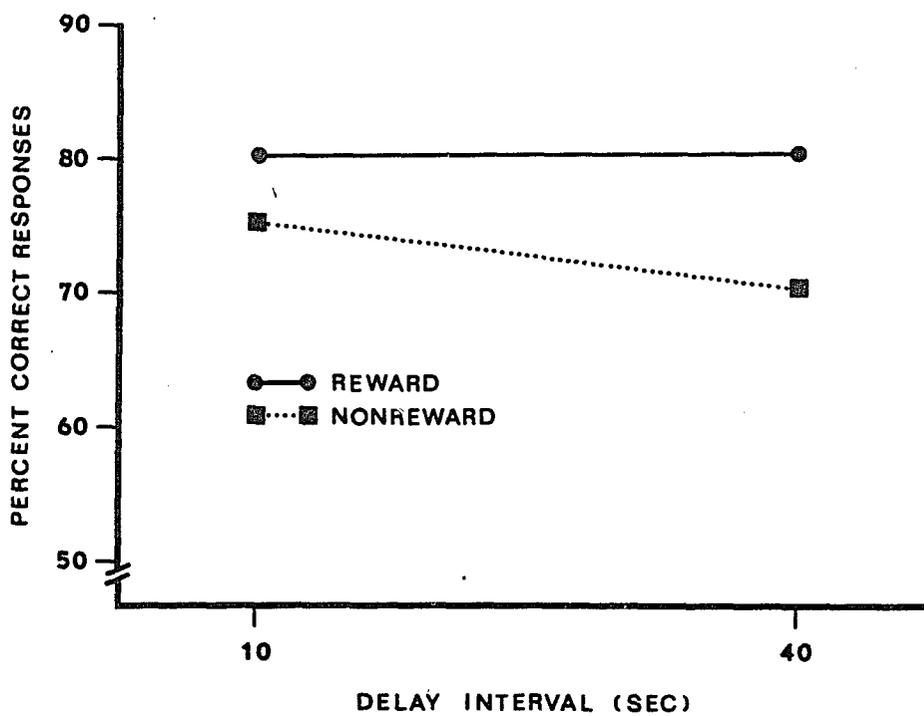


Figure 3. Mean Percent Correct Responses for Reward and Nonreward Conditions as a Function of Delay Interval

and Grant 1976), the subjects in the present study displayed no evidence of poorer retention after a 40-second interval than after a 10-second interval. This somewhat surprising finding is, however, consistent with the interaction between stimulus set size and delay interval reported by Moise (1976). Moise found a less steep forgetting function for DMTS with a stimulus set of seven items than with only two items. If a significant reduction in the absolute magnitude of the forgetting function is observed when the stimulus set is increased from two to seven items, the finding of a forgetting function slope of essentially zero with a set of 576 stimulus items seems less remarkable. The lack of a delay effect observed in this experiment is also consistent with the relatively weak effects of ITI observed in discrimination learning set studies which also use large pools of stimulus items (keep in mind that stimuli are remembered over delay intervals in DMTS experiments but must be remembered over inter-trial intervals in DLS experiments). For example, Riopelle and Churkian (1958) found that DLS performance was only about 5% poorer with a 60-second ITI than with a 10-second ITI. Bessemer (in Bessemer and Stollnitz 1971) found that following three rewarded acquisition trials, rhesus monkeys were able to respond correctly on 80% of test trials presented after a 24-hour retention interval.

The interaction between delay interval stimulation and blocks indicates that although illuminated delays initially disrupted performance, this effect disappeared as the animals

learned the DMTS task. The loss of an illumination decrement cannot be attributed to a ceiling effect because performance continued to improve after dark delay performance and illuminated delay performance were essentially the same (see Figure 1). A more reasonable explanation is that on illuminated delays, the lowering of the yellow and white opaque screen was initially interpreted as an event equivalent to the lowering of the black screen, i.e., the end of a trial. As training proceeded, the animals learned that the lowering of the delay interval screen was a cue to remember the previously seen sample stimulus. This finding provides evidence that cebus monkeys, like pigeons (Maki et al. 1979) eventually recover from the introduction of novel delay interval stimuli.

The finding of superior rewarded sample performance when compared to nonrewarded sample performance contrasts sharply with DLS studies of trial-1 reward. The superiority of rewarded sample performance is not likely a simple consequence of positive transfer from previous experiments since the learning curves for nonrewarded and rewarded sample conditions remained parallel throughout the experiment. If positive transfer facilitated rewarded sample performance, the learning curves would be expected to converge as training proceeded. Unlike the Moss-Harlow (1947), rewarded sample superiority cannot be explained as a consequence of curiosity or neophobic responses because unlike studies of trial-1 reward effects in DLS, subjects were always required to respond to the object which had previously appeared as sample

regardless of the outcome of the sample response. Rewarded sample superiority in the current experiment also cannot be a function of stimulus preferences which have been known to produce a similar effect on trial-2 DLS performance when two objects are presented in trial-1 (Bessemmer and Stollnitz 1971).

The rewarded sample effect of the current experiment even differs from results obtained in experiments in which the same contingencies between trial-1 and trial-2 responses existed as between sample and choice stimulus responses. In two experiments, Brown et al. (1965) found that both naive baboons and stumptail macaques learned 2-trial discrimination problems faster when they were required to make lose-stay responses on the second trial than when they were required to make win-stay responses. If the sample response in the current experiment is regarded as analogous to the trial-1 response in these experiments then the response strategies enforced in the present experiment can also be described as lose-stay and win-stay. However, two important differences do exist between this experiment and the Brown et al. experiments. The Brown et al. experiments presented different reward contingencies to different groups and two objects were presented on trial-1. Yet, in the present experiment, win-stay and lose-stay conditions were a within subjects variable and a single stimulus was presented as sample.

Another possibly important distinction between this experiment and studies of trial-1 reward in DLS performance is the species of subjects. Nearly all of the studies of trial-1 reward

effects have used Old World monkeys as subjects (but see Boyer 1966), whereas the present experiment used capuchin monkeys, a New World species.

One possible explanation for the rewarded sample effect obtained in the present experiment is based on a process similar to the Law of Effect. The subject may associate the outcome of the sample response with the sample stimulus. Thus if the sample was rewarded, the animal will be more likely to respond to the object again because it remembers the association between the reinforcer and the stimulus. Nonrewarded samples will be less frequently responded to when they occur again as comparison objects for the same reason.

Another possible interpretation is that nonreward following a sample response disrupts performance because of a frustration effect. This explanation suggests that the aversive properties of nonreward creates an emotional state which in turn causes a general performance decrement.

The presence of a significant interaction between delay interval and sample reward condition is also at odds with previous studies of ITI and trial-1 reward (Fletcher and Cross 1964; Boyer 1966). The reason for this discrepancy is unclear but the presently obtained interaction suggests still another interpretation of the rewarded sample effect. Inspection of Figure 3 suggests that forgetting may proceed more rapidly after nonreward than after reward. If the subject develops an association between the sample and the reward, then consumption of the reward

during the delay interval could serve to keep the stimulus trace active longer. When the sample is not rewarded, this quasi-rehearsal mechanism would not be available and forgetting would consequently proceed more rapidly. Frustrative effects of non-reward could also interact with a rehearsal mechanism and increase forgetting regardless of whether the animal associates the outcome of a sample response with the sample stimulus.

CHAPTER 4

EXPERIMENT II

The second experiment was designed to answer a number of questions posed by the results of Experiment I. One such question concerns the generalizability of effects obtained with large set DMTS. Therefore, one of the objectives of the second experiment was to determine whether or not the effects observed for the reward, delay, and illumination variables in large set DMTS also occur in small set DMTS. However, if the two types of task require the same cognitive skills, then the illumination variable may not be effective in a small stimulus set replication of Experiment I using the same group of subjects. The interaction between delay interval stimulation and blocks in the first experiment seemed to imply that subjects learned to use the visual properties of the delay interval screen as a cue to remember the sample. If this is an accurate interpretation of the delay x blocks interaction of Experiment I, then these cue properties should be no less important in small set DMTS where large amounts of proactive interference occur. This implies that illuminated delay performance should be no worse than dark delay performance on the small set DMTS task.

Another group of questions concerns the large set DMTS task. Some of the results obtained in Experiment I could have been a consequence of prior unfamiliarity with the DMTS task. For example, in DLS performance, whether or not ITI is an effective variable may be a function of experience (Bessemmer and Stollnitz 1971). With further training, the monkeys might perform more poorly at long delays than at short delays even when a large set of stimulus items is employed. Similarly the sample reward effects observed in Experiment I may have been a consequence of experience and further training might produce results more in line with previous research.

In order to answer these questions, Experiment II was designed as two concurrently tested replications of the first experiment. One replication tested the effects of the variables manipulated in Experiment I on small stimulus set DMTS while the other simply examined the effects of extended training on large stimulus set DMTS.

Method

Subjects

The same animals used in the first experiment served as subjects in this experiment including the female whose data were not analyzed because of questionable quality. However, approximately halfway through the second experiment, a male subject died. The data collected from this animal prior to its death was

not analyzed. Experiment II followed the first experiment after a period of approximately six weeks.

Apparatus

The apparatus used in Experiment I was also used in the current experiment. Two sets of stimuli were constructed. The large set consisted of 480 junk objects drawn at random from the set of 576 used in Experiment I. The small set consisted of a single pair of highly discriminable objects also drawn from the original set.

Testing Procedure

Each animal was presented with two test sessions daily, one in the morning and one in the afternoon. One of the daily test sessions consisted of a replication of the first experiment with the large set and the other consisted of a replication with a small set. Delay intervals, illumination conditions, and reward conditions were the same as in Experiment I. Time of test session (morning or afternoon), delay interval, and stimulus set size were all counterbalanced so that each of the combinations of delay interval and stimulus set occurred equally often in the morning and in the afternoon.

In the small stimulus set conditions, either object was presented as sample according to a complex stimulus sequence constructed under the following constraints: each object was presented as sample equally often in each of the delay x illumination x reward conditions; each stimulus was presented as the

correct comparison object on the right and left sides equally often in each of the conditions; the same object was never presented as sample on more than three consecutive trials; and both objects were presented as sample equally often within a daily test session.

In the large stimulus set conditions, a unique pair of objects was presented on each trial, with the status of sample assigned randomly. The entire set of 480 objects was scrambled and re-paired at random after every 10 test days.

One subject stopped responding for marshmallow rewards after the first month of testing. The reward for this subject only was switched to small pieces of "candy corn," approximately the same size as the marshmallow fragments used with the other subjects.

Results

Data from this experiment were subjected to three separate analyses. In the first analysis, stimulus set size was treated as a variable resulting in a five factor (blocks x delay x illumination x sample reward x stimulus set) ANOVA design. Once again overall performance increased over blocks, from 71.0% in the first block to 79.9% correct in the last block ($F(4,16)=12.69$, $p<.0001$). Performance was better in dark delay conditions (76.0% correct) than in illuminated conditions (73.9% correct) ($F(1,4)=9.69$, $p<.04$). As in Experiment I, performance was significantly higher when the sample was reinforced (77.3% correct)

than when not reinforced (72.6% correct) ($F(1,4)=12.83$, $p<.02$). In contrast to the first experiment, performance was significantly better with the 10-second delay interval (75.3% correct) than with the 40-second delay interval (72.4% correct) ($F(1,4)=20.73$, $p<.02$). Performance levels were much higher when the 480-object stimulus set was used (89.2% correct) than when the two object set was used (60.7% correct) ($F(1,4)=426.17$, $p<.00003$).

Only one of the two way interactions was significant in this analysis. Stimulus set size interacted significantly with blocks ($F(4,16)=6.50$, $p<.003$). This interaction reflects a more rapid increase in performance in the small stimulus set conditions than in the large (see Figures 4, 5, and 6); however, the difference in slopes of the two learning curves resulted from the large stimulus set performance being nearly asymptotic at the start of Experiment II.

Two three way interactions were significant. Blocks, delay, and stimulus set size interacted ($F(4,16)=3.84$, $p<.03$). This interaction is probably best interpreted as a consequence of a positively accelerated acquisition function for the two-object conditions and nearly asymptotic, negatively accelerated function for the 480-object conditions (see Figure 4). Delay, reward condition, and stimulus set size also interacted significantly ($F(1,4)=32.53$, $p<.005$). Inspection of Figure 7 reveals that forgetting functions for rewarded and nonrewarded samples were essentially parallel or slightly converging for the small stimulus set conditions whereas the forgetting functions for the large set

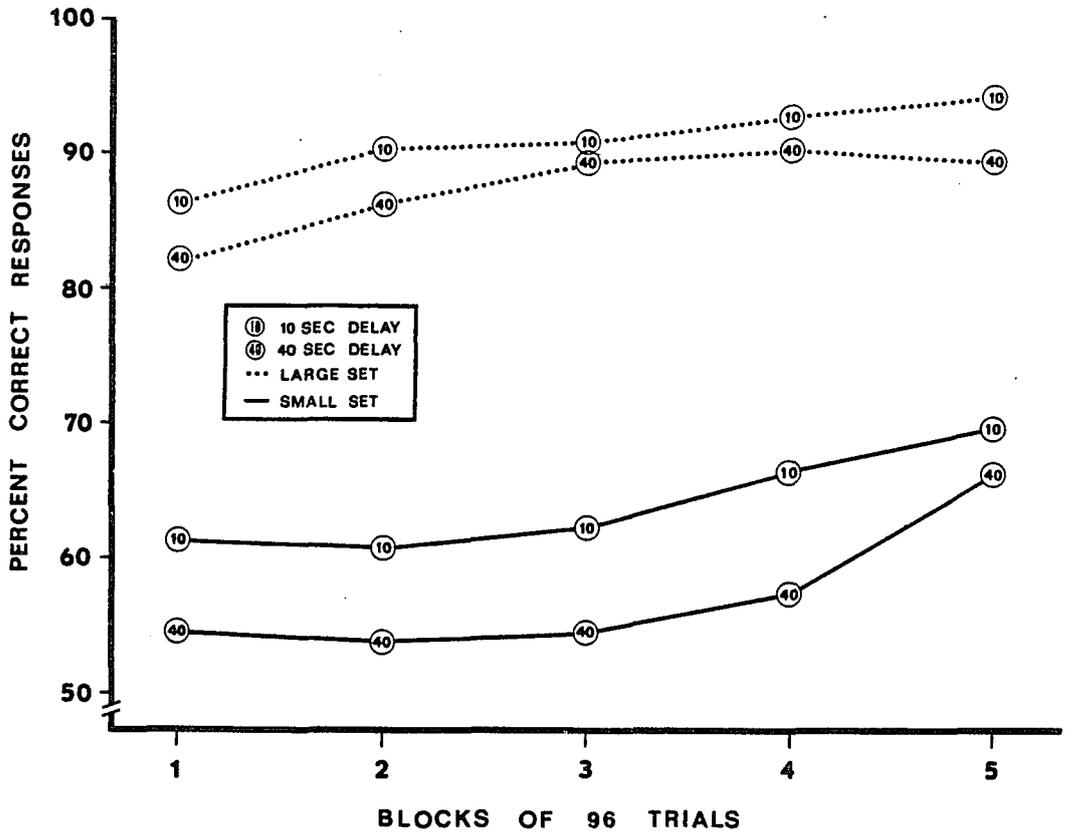


Figure 4. Mean Percent Correct Responses as a Function of Delay for Large and Small Stimulus Set Conditions

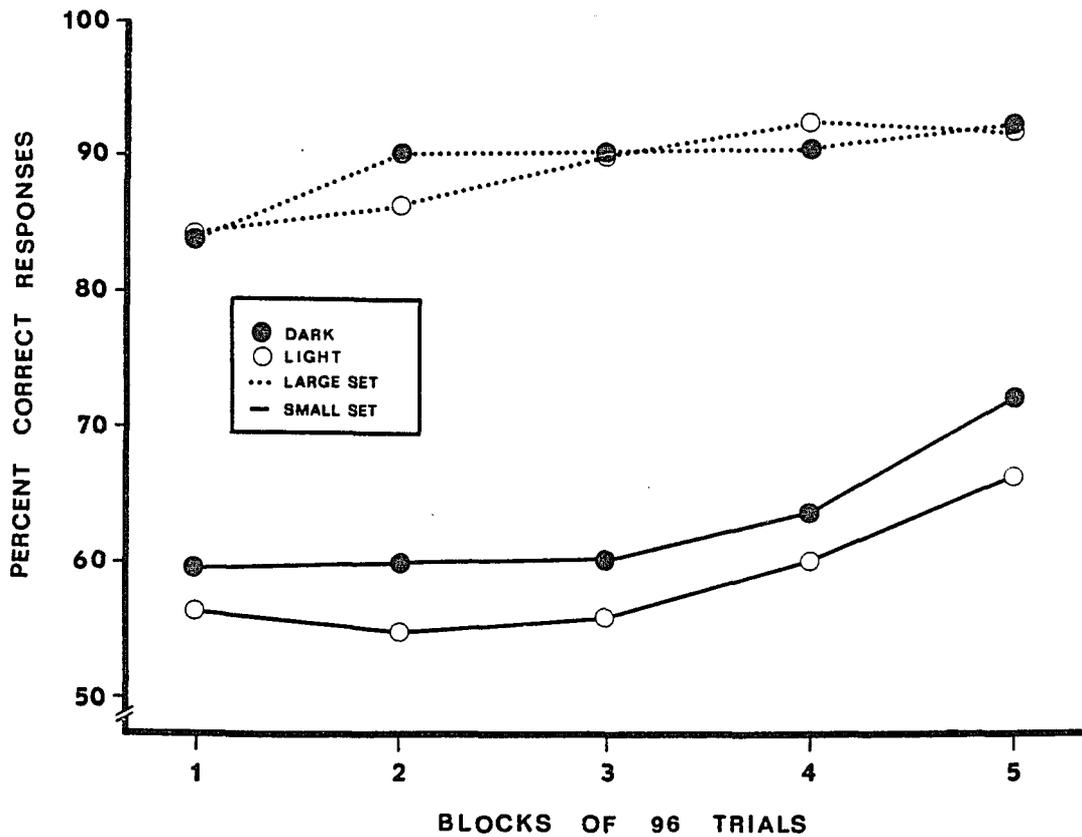


Figure 5. Mean Percent Correct Responses as a Function of Delay Interval Illumination for Large and Small Stimulus Set Conditions

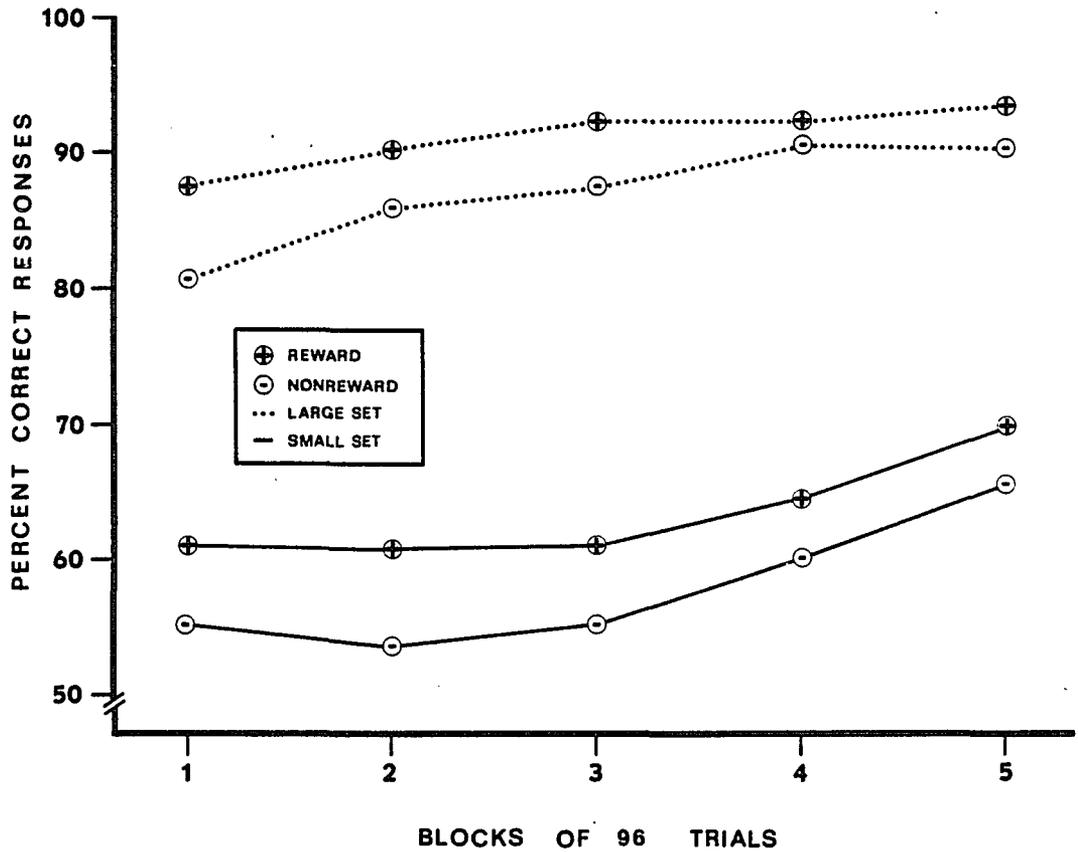


Figure 6. Mean Percent Correct Responses as a Function of Sample Reward for Large and Small Stimulus Set Conditions

conditions were slightly diverging. No 4-way interactions nor the 5-way interaction reached significance.

Separate ANOVAs were used to analyze small and large stimulus set performance. In the large set analysis, performance was again shown to increase significantly ($F(4,16)=16.18$, $p<.0001$) from 84.1% correct in the first block to 91.9% correct in the last block. The delay variable again failed to produce an effect with the large stimulus set ($F(1,4)=6.22$, $p>.05$). In contrast to Experiment I, illumination was not a significant variable ($F(1,4)=0.18$, $p>.05$). Finally, the reward variable again produced significant effects ($F(1,4)=10.48$, $p<.04$) with rewarded sample performance (91.2% correct) superior to nonrewarded sample performance (87.1% correct).

The blocks \times illumination interaction (see Figure 5) was again significant ($F(4,16)=3.62$, $p<.03$) with the large stimulus set; however, due to the essentially equivalent performance in the two conditions, this interaction is not readily interpreted. In contrast to the first experiment, the delay \times reward interaction was not significant ($F(1,4)=1.30$, $p>.05$) although the diverging trend is still apparent (see Figure 7). None of the remaining interactions reached significance in the large set analysis.

The ANOVA for the small stimulus set conditions revealed a significant increase in performance ($F(4,16)=9.24$, $p<.0004$) from 57.9% correct in the first block to 68.0% correct in the final block. In contrast to the large set analysis, 10-second delays (64.2% correct) produced superior performance over

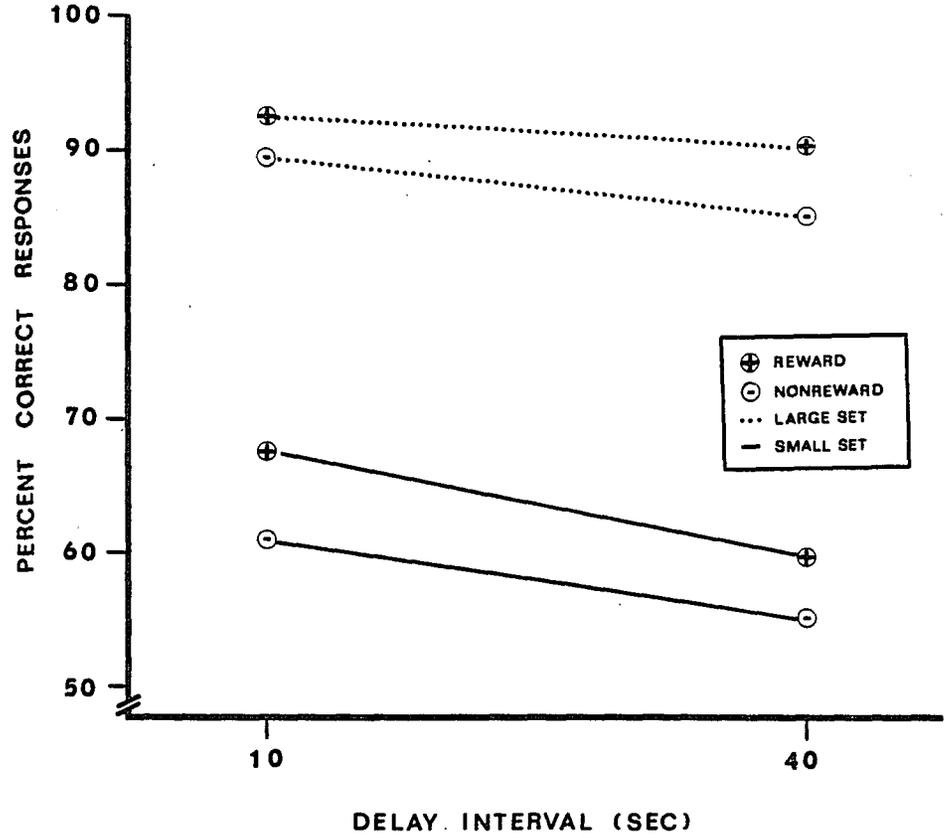


Figure 7. Mean Percent Correct Responses as a Function of Delay Interval and Sample Reward for Large and Small Stimulus Set Conditions

40-second delays (57.2% correct) ($F(1,4)=27.93$, $p<.006$). As in large set DMTS rewarded sample performance (63.4% correct) was superior to nonrewarded sample performance (58.0% correct) ($F(1,4)=9.16$, $p<.04$).

None of the interactions in the small set analysis reached significance. The delay x illumination ($F(1,4)=6.76$, $p>.06$) and delay x reward ($F(1,4)=5.63$, $p>.08$) interactions did, however, approach the .05 significance level.

Discussion

As in Experiment I, performance increased over trials. Inspection of Figures 1 and 5, however, revealed that initial performance on large stimulus set DMTS in Experiment I both started at a higher level and increased more rapidly than on small stimulus set DMTS in Experiment II. The initially lower performance on the small set task suggests that little or no positive transfer from the Experiment I training aided performance in this condition. These results confirm those reported by Mishkin and Delacour (1975, Experiment II). This lack of transfer implies that different cognitive processes may underlie large and small stimulus set DMTS.

As in Experiment I, delay interval was not a significant variable in the large stimulus set condition. It thus appears that the robust recognition memory revealed in Experiment I was not a consequence of inexperienced subjects as learning set studies of ITI effects suggest (Bessemmer and Stollnitz 1971).

In contrast, a significant and persistent delay effect was observed in the small stimulus set condition. This result is typical of other studies of small set DMTS and again supports the notion that steep forgetting functions are a consequence of large amounts of proactive interference. The lack of a delay \times blocks interaction with the small stimulus set condition indicates that the delay effect is not a transitory phenomenon.

Another difference between small stimulus set and large stimulus set DMTS was revealed by the illumination effect. The lack of a large stimulus set illumination effect in Experiment II confirms that the initially poorer performance on illuminated delays in the first experiment was overcome by training. However, the learning responsible for elimination of the illumination effect in Experiment I did not transfer to the small stimulus set condition in Experiment II as evidenced by the significantly poorer illuminated delay performance observed in this condition. Furthermore, the illumination effect in small stimulus set conditions did not dissipate with practice as indicated by the parallel acquisition curves for light and dark delays (see Figure 5). Thus, it appears that the illumination effect is considerably more stable in small stimulus set DMTS.

The presence of a strong reinforcement effect in both the large and small stimulus set conditions (see Figure 6) replicates the effect found in Experiment I and discounts the interpretation that superior reward performance is a consequence of inexperience or transfer effects from previous discrimination learning set

experience. The persistence of this effect after large stimulus set was asymptotic (see Figure 6) which further demonstrates its stability.

The lack of a significant delay by reinforcement effect in the large set condition of Experiment II differs from Experiment I. Figure 7 indicates that 40-second delay performance was slightly lower than 10-second delay performance with the large stimulus set. It may be that still further training would produce a significant delay effect for the large stimulus set condition. The interaction between stimulus set size, delay, and sample reward presents another possible difference between large and small stimulus set DMTS. Inspection of Figure 7 indicates that forgetting functions for rewarded and nonrewarded samples are slightly converging as delay interval increases in the small set condition but diverge in the large set condition. One possible interpretation of this effect is that the greater difficulty of the 2-object task precludes retention of the sample response outcome (memory resources are heavily taxed due to large amounts of proactive interference). However, the converging forgetting functions for the small set condition could also be due to a floor effect for the nonrewarded sample, 40-second delay condition.

CHAPTER 5

EXPERIMENT III

The presence of a strong illumination effect in the small stimulus set condition of Experiment II seemed to indicate that the subjects had not learned to use the visual characteristics of the delay interval screen as a cue to remember the sample stimulus. In view of possible differences between memory mechanisms involved in large and small stimulus set DMTS and recent reports that illumination effects in small stimulus set DMTS by pigeons can be overcome by extended training (Maki et al. 1979; Cook 1980; Tranberg and Rilling 1980), it seemed likely that with further training with illuminated delay intervals subjects might learn to use the delay interval screen as a cue to remember the sample stimulus.

In order to test the hypothesis that animals learn to use delay interval stimuli as cues to recall sample stimuli, Experiment II consisted of two phases. The first phase was an extended training period exclusively with the 2-object, illuminated delay, rewarded sample condition. It was hoped that extended training on this condition would result in higher performance as the animals learned to discriminate the ITI screen from the delay interval screen. The second phase consisted of still further training

on this task but with a number of transfer test trials embedded between control trials. On transfer trials the ITI and delay interval stimuli were reversed so that the intertrial screen was lowered during the delay interval and the delay interval screen was lowered between trials. If the animals had learned to use the visual properties of the screens as cues or instructions, the reversal of these cues would, in effect, tell the animals to forget stimuli during retention intervals and remember stimuli over intertrial intervals (when they should forget previous information to prevent proactive interference). Thus an instruction hypothesis predicted poorer performance on transfer trials.

Method

Subjects

The same animals used in Experiment II served as subjects in the present experiment. Experiment III followed Experiment II after a period of approximately three weeks. During this time the animals were not tested and were fed ad lib.

Apparatus

The apparatus used in the first two experiments was used in this experiment but with a few minor modifications. A third opaque screen, painted gray and manually operated, was mounted between the subject's holding cage and the ITI and delay interval screens. The purpose of this screen was to obscure the other screens while their sequencing was being altered on transitions

from control to test trials in the second phase of the experiment. The same two stimulus objects that were used as stimuli in the small set of Experiment II were used in this experiment.

Testing Procedure

As in Experiment II, each animal was tested twice daily. In the first phase, subjects were given 1,296 training trials with the same delay and intertrial stimuli that they experienced in the illuminated delay conditions of the first two experiments. That is, upon initiation of the intertrial interval the black screen was lowered and upon the initiation of the delay interval the yellow and white screen was lowered. Trials were organized into 3-trial problems each terminated by the lowering of the grey screen after the subject's response on the third trial. Each of the two daily test sessions consisted of 36 trials (12 problems).

In the second phase, testing proceeded as in Phase 1 with the exception that one or two of the 12 problems within each session consisted of transfer test trials. The sequence of events within a test problem were as follows: (1) while the grey screen was lowered to obscure the subject's view, the black (previous ITI cue) screen was raised and the yellow and white (previous delay interval cue) screen was lowered; (2) the grey screen was raised to reveal the yellow and white screen (new ITI cue); (3) the yellow and white screen was raised to reveal the sample object; (4) after the subject's response, the black screen was lowered (new delay interval cue); (5) upon completion of the

delay interval, the black screen was raised for the choice presentation; (6) after the subject's response, the yellow and white screen was lowered to initiate the ITI; and (7) steps 2-6 were repeated for the last two trials of the problem. The grey screen was lowered after the final test trial and the normal sequence of events (i.e., black screen initiates ITI, yellow and white screen initiates delay) was established for control trials.

Both the intertrial interval and the delay interval of both phases of the present experiment were 15 seconds. Interproblem intervals were five seconds. As in the small stimulus set condition of Experiment II, stimulus sequences were constructed so that each object was rewarded as choice object equally often in the right and left positions of the stimulus tray and neither the same object nor the same position was rewarded on more than three consecutive choice tests. These constraints held for both the transfer and control trials in Phase 2.

Results

Phase 1 performance decreased from a mean of 68.7% correct in the first 144-trial block to 61.67% correct in the final 144-trial block. This decrease, however, was not significant ($F(8,32)=1.64$, $p>.05$).

Comparison of performance on the transfer trials (63.61% correct) and control trials (61.0% correct) revealed slightly poorer performance on the control condition than on the experimental condition. The difference was, however, not significant

(t correlated (4)=-1.27, $p > .05$ one tailed test). Individual t -tests revealed that performance in both the experimental and control conditions was significantly above chance ($t(4)=15.26$, $p < .0001$; and $t(4)=8.03$, $p < .001$; respectively, one-tailed tests).

Discussion

The failure of subjects to improve in performance on the 2-object, illuminated delay task in Phase 1 reveals continued disruption by the visual stimulation provided during the delay interval. Essentially equivalent performance on the experimental and control tasks indicates that subjects did not use the visual properties of the delay screens as a cue to remember stimuli. It may be that the motion of the delay and intertrial interval screens is a far more salient cue than the other visual properties and was the only effective stimulus in controlling the animals' performance. If subjects only attended to the downward motion of the screens then the ITI and delay screens would have been essentially indistinguishable, producing an effect much like that reported by Motiff et al. (1969) in delayed-response performance.

The fact that subjects were able to overcome the disruptive effects of the delay interval screen in the large stimulus set conditions of Experiments I and II contrasts with their inability to overcome these effects in the small stimulus set conditions of Experiments II and III. This may indicate that the information stored in large set DMTS is less subject to

disruptive effects occurring during the retention interval than is the information which controls responding in small set DMTS.

CHAPTER 6

EXPERIMENT IV

One possible explanation for the change in delay interval stimulation effect is that such changes are surprising and therefore disrupt the processing of less recent inputs to short-term memory because they receive greater access to a limited capacity rehearsal mechanism (Cook 1980; Tranberg and Rilling 1980). Most of the evidence for such effects of surprising stimulation has been collected in studies of Pavlovian conditioning. For example, a series of experiments by Wagner, Rudy, and Whitlow (1973) demonstrated that conditioning proceeds much more slowly when conditioning trials are followed by surprising events than when they are followed by expected events. Surprising posttrial events are thought to disrupt conditioning because they capture the limited capacity rehearsal mechanism and displace representations of the recently input CS and US. Since the US and CS representations spend little time jointly stored in short-term memory, a relatively small increment in the strength of the associative bond between these two stimuli will be produced.

An unexpected or surprising event, according to Wagner (1978), is one which is not predicted by the total aggregate of cues which precede it. In a study of DMTS performance in pigeons,

Maki (1979b) manipulated the predictability of sample stimuli by prior cues. In this experiment, subjects were trained on a conditional delayed match to sample procedure in which a sample of food was represented by a red comparison stimulus and a sample of no food was represented by a green comparison stimulus. These animals were also concurrently trained on a discrimination task in which a vertical line (S^+) signalled two seconds of availability of food and a horizontal line signalled two seconds of blackout (no food). After establishing that the birds had learned the predictive value of S^+ and S^- , the discrimination and conditional DMTS tasks were chained together on probe trials so that S^+ and S^- predicted subsequent food and no food samples. On half of the probe trials the original contingency between presentations of S^+ and S^- and the delivery of food was maintained (expected sample condition). On the remaining trials, the contingency was reversed so that S^+ was followed by a no food sample and S^- was followed by a food sample (unexpected sample condition). As predicted by the surprise hypothesis, unexpected samples were remembered better than expected samples.

Although Tranberg and Rilling (1980) have argued that a similar surprise mechanism is an unlikely explanation for delay interval stimulation change effects in DMTS performance due to their persistence, it remains possible that surprising delay interval stimuli could serve as an effective, albeit transient, source of retroactive interference. The present experiment was designed to determine whether an unexpected event would interfere

with the recognition of a choice stimulus previously seen as a sample in the DMTS paradigm. A change in the sample reinforcer seemed a logical choice for a surprising event for a number of reasons. In Experiment III, the subjects had performed 2,196 DMTS trials in which they found a marshmallow or candy corn reward under the sample object 100% of the time. Thus, the incentive with which the subject had been trained would be predicted with apparent certainty by the collection of cues common to the sample presentation phase of a trial. A change in the quality of this reward would therefore constitute a highly surprising event. A reward change is also a good choice for a surprising event because, unlike illumination changes and changes in the visual properties of a delay interval opaque screen, incentives are emotionally significant stimuli and are likely to be attended to. Finally, a change in reward quality would avoid problems of interpretation which might arise if an aversive or frightening stimulus was delivered during the delay interval. Although such noxious stimuli will be surprising to the subjects, it would be impossible to determine whether a decrement in choosing the correct choice object was a consequence of forgetting or an association between the sample stimulus and the noxious event.

Method

Subjects

The animals used in Experiments II and III were subjects in the current experiment. Testing began immediately after completion of Experiment III.

Apparatus

The apparatus used in the previous experiments was used in Experiment IV but with a few modifications. The opaque screens previously used to indicate delay and intertrial intervals were removed and the manually operated grey screen was used to obscure the subject's view during the ITI. A different method of preventing the animals from viewing the stimulus tray during the delay interval than had been used in previous studies was used in the current experiment. A cloth curtain, measuring 15 cm by 30 cm, was hung parallel to and 30 cm behind the forward opaque screen. After a response to the sample object, the tray was withdrawn behind the curtain so that the experimenter could position and bait the choice objects without observation by the subject.

In order to prevent the subject from seeing the sample object after retrieving the reinforcer, a large open space (5 cm by 10 cm) was cut into the stimulus tray immediately behind the sample foodwell. Thus, when the animal pushed back an object in the center position, it would fall off the tray into a cloth pocket, mounted out of the subject's view, 10 cm below the tray.

Fifty-two stimulus objects from the large set of 480 used in Experiment II were selected at random to serve as stimuli in this experiment. These objects were scrambled and re-paired at random after each test session.

Testing Procedure

As in Experiments II and III, the animals were tested twice daily. To insure a reasonably high level of performance and to adapt the subjects to changes in the test procedure, an adaptation phase was again presented prior to the experimental phase. This phase consisted of eight 26-trial test sessions with the sample object always baited with the familiar incentive.

In both the adaptation and experimental phases, a single test trial proceeded as follows. The center position was baited, the sample object was placed over the center foodwell, and the stimulus tray was positioned immediately behind the forward opaque screen prior to the start of the trial. The trial began when the forward opaque screen was raised. As soon as the subject displaced the sample object and retrieved the incentive, the stimulus tray was withdrawn behind the curtain and a manually operated timer was started. During the 15 second delay interval which followed, the experimenter positioned the choice objects in the outer two foodwells and baited the correct (sample) object with a reward. Upon completion of the delay interval, the stimulus tray was pushed forward through the curtain to allow the subject a choice response. After the subject's response the grey

screen was lowered and a 15 second manually timed ITI followed. As in Experiment III the side lamps of the WGTA remained illuminated throughout testing.

Upon completion of the adaptation phase, the experimental phase began. In this phase testing proceeded exactly as it had in the adaptation phase with the exception that two of the daily DMTS trials consisted of test trials in which the incentive placed under the sample object was one-half fresh grape. This "unexpected" reward was selected on the basis of a preference test conducted in the animals' home cages prior to Experiment III. The preference test consisted of presenting a marshmallow (or in the case of one subject, a candy corn fragment) and a grape simultaneously in separate hands and noting which food was selected and consumed first. The preference test was repeated three times and in every instance the grape was selected and consumed first. It was important to establish that the unexpected incentive was preferred over the expected incentive since it has been demonstrated that delayed response performance is superior with more preferred incentives than with less preferred incentives (Berkson 1962).

The experimental phase consisted of 24 test sessions. Forty-eight trials were embedded within 288 control trials in which the familiar incentive was placed under the sample object.

Stimulus sequences were constructed such that the right and left choice positions were rewarded equally often in a test session and under the constraint that on no more than three

consecutive trials was the same position rewarded. In the experimental phase, the rewarded choice position on probe trials was similarly counterbalanced. The position of probe trials within a session was also counterbalanced so that after every 12 test sessions a probe trial had followed each of the 24 control trials presented in a single session.

Results

Performance in the adaptation phase increased from a mean of 69.58% correct in the first 48-trial block to a mean of 81.65% correct in the final 48-trial block; however, this increase was not significant ($F(3,12)=3.05$, $p>.05$). In the two blocks of the experimental phase, performance increased from 82.29% correct to 85.42% correct on control trials and from 69.17% correct to 78.33% correct on experimental trials; yet, again this increase was not significant ($F(1,4)=5.90$, $p>.05$).

Informal descriptions of subject behavior by testers revealed that on the first two-three days of the experimental phase sight of the unexpected reward (grape) evoked marked surprise reactions. Noticeably longer latencies to retrieve grape pieces than to retrieve familiar rewards were observed. On unexpected incentive trials, some animals jumped back and withdrew their hand after displacing the sample object.

Experimental phase performance on trials with the expected sample incentive was superior ($\bar{X}=83.85\%$ correct) to trials with the surprising sample incentive ($\bar{X}=73.75\%$ correct)

($F(1,4)=26.00$, $p<.008$). Although Figure 8 indicates a more rapid increase in performance over blocks on probe trials than on control trials, the interaction between blocks and conditions failed to reach significance ($F(1,4)=1.0$, $p>.05$). Inspection of the data from individual subjects revealed that four of the five monkeys' performance on Block 2 was much less disrupted by the unexpected sample reward than on Block 1; yet, a single subject's probe trial performance worsened in Block 2 (see Table 1). Thus, the lack of a block by condition interaction may be due to the atypical performance of a single animal.

Discussion

The finding of inferior performance on probe trials with a grape as sample object reward indicates that unexpected events can disrupt the recall of prior stimulus information. The rapid attenuation of this surprise effect as evidenced by the large improvement in performance by four subjects in the second 24-trial set of probe trials gives an indication of its relatively transient nature.

The retroactively interfering effects of a surprising reward observed in the present experiment may seem to conflict with the results of other studies using different experimental paradigms which indicate that unexpected reinforcers are more rather than less effective. Blanchard and Honig (1976) presented pigeon subjects with food in one houselight condition (S^+) and no food in another houselight condition (S^-). Subsequent

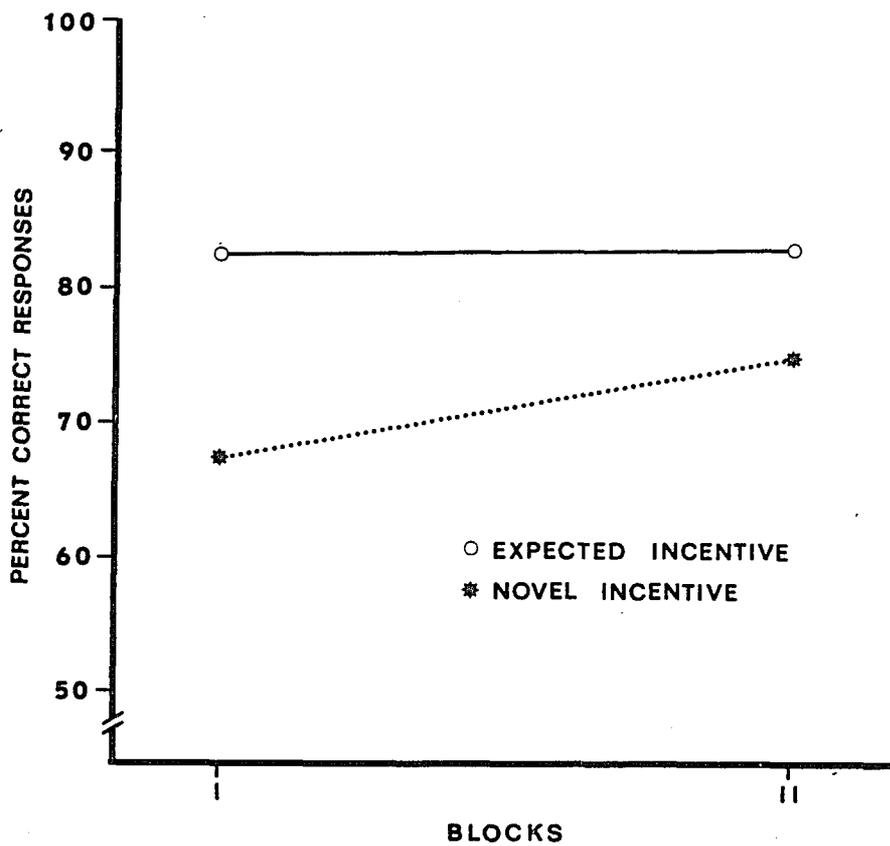


Figure 8. Mean Percent Correct Responses for Unexpected and Expected Sample Reward Trials

Table 1. Mean Percentage Correct Responses with Expected and Unexpected Sample Incentives

Subject	187	195	193	196	188	\bar{X}
Block 1						
Expected	74.30	85.07	90.28	71.43	84.38	81.09
Unexpected	79.17	62.50	79.17	58.33	66.67	69.17
Difference	-4.87	22.57	11.11	19.10	17.71	13.12
Block 2						
Expected	82.29	86.11	90.28	81.94	86.46	85.42
Unexpected	66.67	75.00	87.50	79.17	83.33	78.33
Difference	15.62	11.11	2.78	2.77	3.13	7.09

autosshaping to a white key proceeded faster when the S^- houselight was on (i.e., when food was unexpected) than when the S^+ houselight was on (i.e., when food was expected). Terry and Wagner (1975) have also demonstrated that an unexpected aversive US is a more effective Pavlovian reinforcer than an expected aversive US. Furthermore, at least one recent theory of Pavlovian conditioning has stated that reinforcers (USs) are effective only when they are not predicted by the CS with which they are paired (Rescorla and Wagner 1972). Learning in this model is assumed to be complete when the subject fully expected the US after a CS presentation.

The apparent conflict between the results of the present study and those mentioned above can be resolved if one assumes that an association between an incentive and the sample stimulus

does not control DMTS performance. Such a mechanism is certainly not necessary or else the DMTS procedure commonly used with pigeon subjects (nonrewarded sample presentations) would be totally ineffective. These results may instead indicate that incentive and sample stimuli are separately encoded rather than associated in short-term memory in the DMTS task. Disruptive effects occur when the incentive encoding receives greater access to a rehearsal mechanism than the sample stimulus.

CHAPTER 7

GENERAL DISCUSSION

The first two experiments tested the effects of delay interval, delay interval stimulation, and sample reward on DMTS performance when the sample and comparison objects are either drawn from a large or a very small set of objects. In many instances, these variables exerted different effects depending upon the size of the set of stimulus objects.

Comparison of learning rates in the first two experiments indicated that small set DMTS is learned much more slowly than large set DMTS even when small set training is imposed after the animals have already learned large set DMTS. This is consistent with the results of previous research with rhesus monkeys (Mishkin and Delacour 1975, Experiment II) which indicated that previous 2-object DMTS training transfers to subsequent large set DMTS performance but that large set DMTS training does not transfer readily to 2-object DMTS.

The facts that small and large set DMTS tasks are learned at different rates and that large set training does not transfer readily to small set performance, do not necessarily imply that different processes are involved in the two tasks. If DMTS performance is a function of a discrimination process, then these

results could be expected simply because the discriminations to be made in small set DMTS will be difficult either because the trace strength of both choice objects is great or because both objects have been seen relatively recently.

One result in the present study which possibly indicates a difference in the memory processes mediating the two tasks was that loss of a delay interval stimulation effect in prior large set DMTS training did not transfer to small set DMTS performance. Although interpretations are at this point best treated as speculation, a separate process explanation is consistent with these results. Early in large set DMTS training, the animal may be learning to encode the sample stimuli into long-term storage. Before this learning process is complete, certain delay interval stimuli may act to prevent the encoding of a complete representation of the sample stimulus; however, with extended training, the long-term encoding process becomes resistant to the effects of delay interval stimulation. In contrast, small set DMTS performance may require two types of memory representation. The first would be long term representation of all stimulus items. These would develop rapidly over trials since all stimulus items are seen very frequently (in 2-object DMTS all objects are seen on each trial). The second type would consist of a rapidly decaying short-term memory representation of either an instruction (e.g., "go to stimulus A") or a marker indicating which object is most recent.

In the present set of experiments, lowering the delay interval screen would have no effect on the long-term encoding process once it had fully developed. However, the second type of memory representation would require some type of active rehearsal process to bridge the delay interval. Previous experience would have taught the animals used in the current studies that the lowering of an opaque screen signifies the end of a trial and consequently the end of a need to rehearse predelay information. In order for these animals to improve illuminated delay, 2-object DMTS performance in Experiments II and III, it would therefore be necessary for them to learn to discriminate the delay interval screen from the ITI screen. The results of the transfer tests in Experiment II clearly demonstrate that such learning did not take place, thus explaining the persistent illuminated delay performance decrement in the small set condition.

The current set of studies supply at least one piece of evidence that large set DMTS is a function of a long-term memory storage while small-set DMTS is controlled by an active rehearsal process in short-term memory. In both Experiments I and II, delay interval had no effect on large set DMTS; this clearly indicates that whatever type of memory representation is used to bridge the delay interval in this task, it must be relatively permanent. In contrast, small set DMTS performance in Experiment II deteriorated rapidly with increases in the delay interval. Furthermore, the inferior long delay performance in the small set condition was not overcome with training as indicated by the lack

of a delay by blocks interaction. This analysis could be criticized since the relatively brief 40-second delay interval performance was used as evidence for a long-term memory process dominating large stimulus set performance and future research clearly should examine rates of forgetting in this task over a much wider range of delay intervals. However, studies of the very similar discrimination learning set task indicate relatively little forgetting after only three acquisition trials even when the retention interval is as long as 24 hours (Bessemmer in Bessemmer and Stollnitz 1971).

In contrast to the effects of training, delay interval, and delay interval stimulation, a clear superiority for rewarded over nonrewarded sample performance was observed in both the large and small set procedures. One possible explanation for this effect is that animals associate reward events with sample stimuli and that these associations guide choice responses; however, this does not explain why the opposite effect (i.e., superior nonrewarded over rewarded performance) was obtained in studies of reinforcement effects in macaques on discrimination learning set tasks.

Another possibility is that nonreward induced frustration created a general performance decrement in the post-delay choice responding of the capuchin monkeys used in the current experiments. Future studies using between subjects design may help to resolve the conflicting results obtained in this and earlier studies.

The results of Experiment IV indicated that unexpected sample rewards disrupt DMTS performance even though they are more highly preferred than expected rewards. This result was interpreted as evidence that subjects store sample stimulus representations and sample response outcomes separately and that unexpected sample response outcomes displace sample stimulus representations from short-term memory by capturing a limited capacity rehearsal mechanism. This is, of course, contradictory to the interpretation of sample reward effects based on an association between the sample and incentive. If an association existed between the sample stimulus and its reward event, a more preferred incentive would be expected to produce more correct responding than a less preferred incentive (cf. Berkson 1962). Furthermore, studies of classical conditioning have demonstrated that surprising USs produce CS-US associations more rapidly than expected USs (Terry and Wagner 1975; Blanchard and Honig 1976). It is possible that associations were not formed between the sample stimulus and reward or nonreward events because the outcome of a sample response was irrelevant to the post delay choice response.

The results of the final experiment in this series suggest that novel sample incentives could be used as a powerful tool to study retroactive interference. One advantage of this technique is that it is apparently free of the problems of interpretation which exist with interpolated choice stimuli:

unexpected incentives are not likely to be confused as sample stimuli by the subject whereas an interpolated choice stimulus may be.

The results of the present experiment suggested that the disruptive effects of novel sample incentives are lost fairly quickly as subjects become more and more familiar with them. Future research should examine the effects of experience upon this phenomenon. In addition, the experiment reported here incorporated an intermediate sized stimulus set (52 objects) to achieve a relatively high level of performance without totally sacrificing stimulus familiarity. The analysis of stimulus set size effects reported above proposed a greater role of an active rehearsal mechanism in small set DMTS than in large set DMTS. Thus, to better understand the generality of this phenomenon, it will be necessary to assess the effects of novel sample reinforcement with large and small stimulus sets.

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