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By

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ABSTRACT

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By

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A successive delayed matching-to-sample procedure was modified to determine if stimulus control of rehearsal processes could be obtained. Procedures were modeled after the directed forgetting procedures commonly used in human memory studies. Cues during the interstimulus interval signalled the occurrence (remember cues) or nonoccurrence (forget cues) of comparison stimuli. Memory strength remained constant on remember cued trials regardless of the temporal location of the cue within the interval. Evidence indicates that rehearsal processes were terminated on trials in which the forget cue was given. Consequently, memory strength varied as a function of cue location on those trials, with early cues leading to poorer matching performances than late cues. A control condition established that the important variable involved in the effectiveness of a forget cue was the interval between the forget cue and the comparison stimulus. Results demonstrate stimulus control over an active rehearsal process in the pigeon.

To My Wife, Regina, Whose
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INTRODUCTION

The 1960's saw the advent of a new approach to human processes, formally born with the publication of Ulric Neisser's Cognitive Psychology (1967). After 50 years or so of suppression through the prevalence of behaviorism, researchers once again began to ask questions about the higher mental processes studied by the structuralists. At the heart of this new perspective was the assumption that human beings are active, information seeking and using organisms contrary to the mechanistic view of the radical behaviorists regarding human beings as passive accumulations of associations (see Reynolds and Flagg, 1977, Chapter 1). Cognitive psychology used the methods perfected by the neo-behaviorists, along with concepts and techniques borrowed from the new fields of linguistics, computer science and information theory, to study the mental structures and processes of attention, language perception, learning and memory.

Work on the nature of memory processes has been one of the focuses of the cognitive movement. One particular concept that has been useful in this research is the distinction between short- term and long-term memory. Short-term memory (STM) is considered to be of limited capacity and short duration (information is quickly lost if not actively rehearsed) while long-term memory (LTM) is of a more permanent nature. Despite the fact that there is not universal acceptance of STM and LTM as a conceptual distinction, few would argue its usefulness as an operational distinction. Dividing memory into short-term and long-term processing components has been a useful tool in describing and explaining many aspects of memory processing. The idea of a two component memory system in humans is an old one. Psychologists as early as William James have made a distinction between "primary and secondary memory" (James, 1890). Physiological evidence such as Milner's syndrome (where victims of neural damage are unable to remember events in the recent past, but can remember events in the remote past) also seemed to indicate separate memory processes of short and long duration. It was not until the late 1950's, however, that there was any widely recognized empirical support for a two component memory system. This evidence came with the development of a new technique by Brown (1958) and by Peterson & Peterson (1959) that demonstrated rapid forgetting in humans. The Brown-Peterson technique consisted of presenting a single verbal item for retention, employing a distraction task to prevent rehearsal, and testing retention after some variable length retention interval. Peterson and Peterson found retention to decrease monotonically with the length of the retention interval. They found that the near perfect retention at three second retention intervals decreased steadily to very low retention (10%) at 18 second retention intervals. No one prior to Brown and the Petersons had thought to look for memory loss at such short retention intervals--memory loss functions had typically been plotted in terms of hours and days rather than seconds. This major advance allowed the assessment of short-term memory and rapid forgetting, opening the doors to diverse possibilities in memory research.

Directed Forgetting

Within the realm of memory research an area that has been extensively studied is directed forgetting. During the 1960's the main focus in human memory research was on intentional remembering and incidental forgetting. While this line of research adequately dealt with a great deal in the area of memory processes, there were still some aspects which were inaccessible. Bjork, LaBerge and LeGrande (1968) developed the procedure of directed forgetting in order to get at some of these unanswered questions. Directed forgetting, with its focus on intentional forgetting and incidental remembering, (Woodward & Bjork, 1971), was the next step in the progression of human memory research. As Bjork (1972) puts it, the primary concern of directed forgetting research is to understand how current to-be-remembered information is discriminated from past to-be-forgotten information. Bjork points out how vital this updating process of intentional forgetting is in everyday life. Realizing the vast amount of information a human comes in contact with during the course of a day, it would be both uneconomical and counterproductive for a person to attempt to remember all of the information that is attended to. Directed forgetting procedures provide an empirical situation that allows investigation of how these items are differentiated in memory.

In the basic directed forgetting procedure a subject is given a set of items to memorize (usually words or trigrams).

Some of these items are followed by a remember (R) cue and others are followed by a forget (F) cue. These cues either follow a series of items (blocked cueing procedure) or each individual item (item by item cueing procedure). The R cue indicates that the subject will be required to remember the to-be-remembered (TBR) items while the F cue indicates that the subject does not need to remember the to-be-forgotten (TBF) items. It is often pointed out to the subjects that remembering the TBF items is counterproductive and that the best strategy is to forget those items. Following the presentation of the TBR and TBF items retention tests are given to access the memory for those items. Subjects are tested for items that they knew they were going to be tested on (TBR items) as well as items they were misled to believe they would not be tested on (TBF items).

Using the directed forgetting technique within a modified version of the Brown-Peterson procedure several researchers have found that subjects are very capable of utilizing R and F cues in their memorization processes. Recall of TBR items is consistently better than recall of TBF items (Bjork, 1970; Bjork, LaBerge & LeGrand, 1968, Block, 1971; Davis & Okada, 1971; Elmes, Adams & Roediger, 1970; Epstein, 1970; Woodward & Bjork, 1971; Woodward, Bjork & Jongeward, 1973). According to Jongeward, Woodward, and Bjork (1975) the primary effect of cueing a portion of the items in a list as TBF items is a drastic reduction in the retrievability of those items. Secondly, instructing subjects to forget some of the items reduced the amount of interference of these TBF items (Bjork, et al., 1968; Block, 1971) on TBR items. This reduced interference leads to an enhanced retention of those TBR items. The combination of a reduction in retrievability of TBF items and reduced interference produces a very stable phenomenon in the relative superiority of the retention of TBR items over TBF items.

Explanations for the directed forgetting phenomenon usually emphasize either input mechanisms or output mechanisms. Bjork and his colleagues have focused primarily on the influence of input mechanisms. Bjork (1972) proposed two mechanisms as the controlling variables in directed forgetting: differential rehearsal of TBR and TBF items and differential grouping of these items to functionally separate them in memory. Bjork believes that the superior retrievability of TBR items is due to a combination of these two factors. Epstein and his colleagues focus on output rather than input mechanisms, and have questioned the necessity of rehearsal in accounting for the basic directed forgetting effect (Epstein, 1972; Epstein, Massaro & Wilder, 1972; Shebilske, Wilder & Epstein, 1971). These researchers rely solely on a selective search hypothesis based on the partitioning of TBR and TBF items to account for the effectiveness of the forget cue. Recent studies seem to indicate that the weight of evidence favors the position of Bjork (Jongeward et al., 1975; Wetzel, 1975; Wetzel & Hunt, 1977; Woodward, Park & Seebohm, 1974). These studies reconfirm the important role of rehearsal and other processing mechanism at input. These findings are contrary to Epstein's sole reliance on search and retrieval processes at output. Bjork

(1972) points out that selective rehearsal and differential grouping are integrally related and that the two mechanisms co-imply each other. "That is, efficient selective rehearsal of R items as a set, and the differentiation of R items as a set may depend on their being rehearsed together" (P. 229). Rehearsal processes seem to be integrally related to the directed forgetting effect and must therefore be accounted for in any theoretical explanation of the phenomenon.

Levels of Processing

Craik and Lockhart (1973) draw an important distinction between primary and secondary rehearsal, each of which is a different class of rehearsal processes. While some researchers have placed less emphasis on the levels of processing approach (Baddeley, 1978) it still appears to be a useful framework for a great deal of memory research. Primary (Woodward et al., 1973), Type I (Craik & Lockhart; Glenberg & Adams, 1978) or maintenance (Craik & Watkins, 1973) rehearsal is primarily associated with STM, and is assumed to maintain information by rote repetition. Waugh and Norman (1965) and Atkinson and Shiffrin (1968) propose that rehearsal both maintains an item in short-term store and simultaneously transfers at least part of that information to long-term store. According to this model the probability that an item will be encoded in long-term memory is dependent on the amount of time it is held in short-term memory (Meunier, Ritz, & Meunier, 1972). Other researchers (Craik & Lockhart; Craik & Watkins; Jongeward, Woodward & Bjork, 1975; Glanzer & Meinzer, 1967; Glenberg, Smith & Green, 1977; Tulving, 1966; Tulving & Colotla, 1970) have demonstrated that maintaining information in short-term store does not necessarily affect delayed recall performance. They found no relationship between the two when the rehearsal process that was used to maintain the information was of a rote maintenance (as opposed to elaborative) nature.

In contrast to Type I rehearsal, Type II or secondary rehearsal is highly associated with delayed memory performance. This "deeper" more elaborative type of processing leads to more durable memory traces through the use of greater association formation between TBR items (Woodward et al., 1973), or through greater "processing effort" according to Craik and Lockhart's concept of depths or levels of processing. In directed forgetting studies using words or trigrams as TBR and TBF items, this "depth" implies a greater degree of semantic or cognitive analysis. Through Type II rehearsal the items being rehearsed become actively associated with each other and with other information in long-term memory. Making a distinction between two modes of rehearsal, Craik and Watkins state:

> Time in short-term store will only predict later long-term store performance when the subject has used the time to encode the items elaborately. Contrary to the models of Atkinson and Shiffrin (1968) and Waugh and Norman (1965), time in short-term store does not by itself lead to long-term retention. (P. 603)

Relationship Between Rehearsal Level and Directed Forgetting

In directed forgetting studies the effect of the amount of processing on performance in recognition and recall tests is highly dependent upon whether the rehearsal process being varied is the Type I or Type II nature. For a typical recognition task the subject is asked to identify words that had previously been given from a large set of given words. When recall is tested the subject is simply asked to give as many items as he or she can remember. The presence of the exact items as retrieval cues on a recognition test has lead many to believe that only recall, and not recognition, requires a retrieval process on the part of the subject (e.g., Underwood, 1972) Woodward et al. (1973) have theorized that greater rote maintenance rehearsal increases both recognition and recall.

A presupposition for the position held by Woodward et al. is the common sense notion that the memory of an item will vary directly proportionally to the amount of rehearsal that has been allowed for that particular item (this line of reasoning is of course essential to Bjork's hypothesis on the role of selective rehearsal in directed forgetting). Strangely, initial studies failed to support even this simple relationship between amount of rehearsal (rote or elaborative) on memory of an item as tested by either recall or recognition tests. Davis and Okada (1971), using an item by item cueing procedure, attempted to manipulate the amount of rehearsal by using either a delay or no delay between an item and the cue to forget. Delay of cueing in the input list did not have any marked effect on either recall or recognition of TBR or TBF words. One very serious drawback in the design of the Davis and Okada study was that they only used delays of 0 and 1 seconds. This range was too minimal to examine any real effect the amount of rehearsal may have had on subsequent recall and recognition tests.

Woodward and Bjork (1971) also failed to demonstrate a relationship between amount of rehearsal and later memory strength using work presentations that were 1, 2, or 4 seconds before the cue to remember or forget was given. A drawback in the design of their study was that each word remained in view until the cue appeared. It is very conceivable that in this situation the amount of rehearsal was not varied at all. The subjects in Woodward and Bjork's study could very easily have avoided any active rehearsal of the work being presented until the cue was given.

Contrary to the above findings (or perhaps more accurately the lack of findings) were the findings of Glenberg, Smith and Green (1977) and Meunier, Ritz and Meunier (1972) that there was a direct relationship between rehearsal and retention. Although not using directed forgetting procedures, these investigators used a modified version of the Brown-Peterson procedure to demonstrate a direct relationship between amount of Type I rehearsal and recognition. A similar relationship was also found between the rehearsal and performance on an immediate (but not delayed) recall test.

Woodward et al. (1973) were dissatisfied with the counter-intuititive inability of previous directed forgetting studies to show this positive relationship between amount of rehearsal and retention. They set out to eliminate the procedural aspects of the Davis and Okada and the Woodward and Bjork studies which seemed to have confounded the results. Woodward et al. used rehearsal periods of 0, 1, 2, 4, 8, and 12 seconds between the offset of the word and the onset of the R or F cue, thereby eliminating the two major flaws previously mentioned in regards to the earlier studies. The various retention intervals were randomly distributed throughout the list in an item by item cueing procedure. They found that the duration of rehearsal had a heavy influence on performance on a final recognition test. However, they were also unable to find any effect of differential amounts of rehearsal on final recall. Woodward et al. suggested that the results they obtained were a function of the type of rehearsal being utilized by their subjects. They hypothesized that their procedure made it inappropriate for subjects to rehearse each word in an active, constructive way, since each word had an equal probability of being followed by a cue to simply forget that word. Associative or integrative (Type II) rehearsal was, according to this account, counterproductive prior to any R or F cue. They therefore offered the explanation that subjects merely engaged in rote nonassociative processing, which was conceived of as independent of long term memory. Glenberg et al. (1977), Jongeward et al. (1975), and Rundus (1977) have shown that the duration of this Type I rehearsal does not affect delayed recall. As previously stated, Glenberg and Adams (1978) demonstrated that the duration of Type I rehearsal does, however, affect the memory trace as measured on a recognition test. It can then be seen that in Woodward et al's study the various amounts of Type I rehearsal of each item produced the resultant effect on recognition performance. Recall performance, on the other hand, heavily depends on interassociations and interrelations between items in memory, as can be seen in Craik and Watkin's (1973) hypothesis that only elaborative rehearsal affects long-term memory. Woodward et al.'s explanation that subjects only engaged in rote primary rehearsal would therefore explain their inability to demonstrate any effect of amount of rehearsal on recall performance.

Further studies by Wetzel (1975) and Wetzel and Hunt (1977) established a direct relationship between amount of rehearsal and both recognition and recall by modifying the techniques of Woodward et al. These studies clearly demonstrated that Woodward et al.'s failure to find an influence of amount of rehearsal on final recall was not as much due to the lack of Type II rehearsal as it was a function of the particular cueing techniques used. Wetzel showed that Woodward et al. failed to produce appreciable differences in recall due to their within list variation of processing opportunities. This technique allowed subjects to rehease previously R cued items during subsequent retention intervals. During any given retention interval subjects were able to time-share their rehearsal of the present to-be-cued item and past TBR items. The net effect was that this procedure equated the amount of processing activity devoted to words that were initially followed by different word-cue intervals (also see Bjork & Geiselman, 1978). Wetzel remedied this situation by varying the amount of rehearsal as controlled by the word-cue delay <u>between</u> lists to ensure a relatively uniform processing opportunity across each list. Using this modified procedure Wetzel and Wetzel and Hunt were able to demonstrate a direct relationship between processing opportunities and performance on both recognition and recall tests.

According to Bjork and Geiselman (1978) the superiority of TBR word recall over TBF word recall in a final recall test is a result of the fact that TBF words are only given an initial amount of rote maintenance rehearsal proportional to the word-cue interval. When a forget cue is presented processing is terminated or inhibited. A remember cue directs the subject to retrieve the word and engage in an elaborative or secondary rehearsal during the remaining cue-word interval, as well as on following trials. Wetzel's studies demonstrate that varying the amount of this elaborative rehearsal results in a directly related variation in final recall in a way quite similar to the previously established relationship between Type I rehearsal and recognition. These results clearly support Woodward et al.'s theory that greater rote maintenance rehearsal increases recognition performance while greater elaborative rehearsal increases both recall and recognition. More generally, Wetzel's and Wetzel and Hunt's results confirm Bjork's hypothesis that differential rehearsal opportunities do contribute to the superior retention of TBR items in the directed forgetting pardigm. In contrasting Wetzel's work with the work of earlier researchers who failed to show such a clear-cut relationship between rehearsal and retention, it can be seen that this effect is highly dependent upon the methods used.

Research on STM in Pigeons

Heavily influenced by research in human processing, researchers in animal behavior have recently incorporated cognitive procedures. Historically, psychologists have applied the findings of animal research to human behavior, based on the principle of biological continuity among species. Animal studies replaced many human studies by virtue of the greater experimental control attainable with subhuman subjects. However, movement on the phylogenetic continuum is not restricted to merely one direction by the principle of biological continuity. Recent authors such as Honig (1978) and Fowler (1978) have started exploring the benefits of applying the findings of cognitive psychology in humans to the study of cognitive processes in animals. A specific example of this trend that is quite relevant to the topic at hand is the parallel between Bjork's statements on the importance of forgetting in human memory processing discussed earlier and Olton's (1978) statement concerning rats, that "If there is limited working - memory capacity, being able to forget is often as important as being able to remember because the memory process will be more effective the fewer items that are already in storage" (p. 352).

In addition to allowing for greater experimental control and a broader range of possible manipulations, the use of animals to study cognitive processes may prove to be helpful in both establishing a theory of animal memory and testing the scope and power of human memory theories. There may well be relevant phenomena inaccessible through the use of human subjects that will be clarified in studies using animals. For example, animal research may help to separate those aspects of human memory that are based on language form those that are not. As Medin (1967) puts it "A theory of animal memory may or may not turn out to be different from a theory of human memory, but either way such information can be of great value" (p. 115).

Memory in animal learning can be defined as stimulus control by a stimulus that is no longer present. There are several possible explanations for the ability of an animal to maintain an item in memory. One of the first explanations of short-term memory in pigeons was that proposed by Roberts and Grant (1976). In Roberts and Grant's basic trace strength and decay model a memory trace exists for each stimulus presented, and that memory trace decays in the absence of the stimulus. More recent investigators have come to realize some of the limitations of the trace-decay model of short-term memory. Although much data can be explained in terms of the relatively straightforward trace strength model, it also seems entirely possible that the existence of a passive trace in memory can be extended, within limits, through an active rehearsal process analogous to Type I or primary rehearsal in humans. Behaviorists have traditionally defined rehearsal as the maintenance of a stimulus that is no longer physically present via some overt mediating behavior (Blough, 1959; Zentall, Hogan, Howard & Moore, 1978). Wagner developed an information processing model of animal memory hypothesizing that information is maintained in STM via a more cognitive process of rehearsal (Terry & Wagner, 1975; Wagner, 1976; Wagner, Rudy & Whitlow, 1973). The ability of pigeons to maintain an item for longer periods of time than would be predicted by a trace strength model seems to favor a rehearsal theory, whether it be cognitive or behavioral. While the recent trend is towards a cognitive interpretation of rehearsal and away from a mediating behavior position, the present experiments will not attempt to distinguish the type of rehearsal mechanism being used. Rehearsal, as discussed in this thesis, could be either cognitive or behavioral. Rather than the nature of the rehearsal process the primary concern here will be the existence of an active as opposed to passive memory process in the pigeon.

Delayed Matching to Sample

Out of the many procedures that have been developed to study STM in pigeons, some of the most fruitful have been methods that evolved from Hunter's (1913) delayed technique. Various delayed response procedures have been used recently to study STM in piegons (Grant & Roberts, 1973; Roberts, 1972; Roberts & Grant, 1974; Shimp & Moffitt, 1974; Zentall, 1973). These delayed response procedures are analogous to the STM procedures used with human subjects that are based on the Brown-Peterson technique. These procedures basically involve presenting an item to be remembered, removing the item from the perceptual field for some interval, and testing for memory of the item. Of these delayed response procedures the various forms of delayed matching to sample (DMTS) have proven to be quite suited for studying variables effecting animal short-term memory.

The successive DMTS is one particular variation of DMTS that has been used quite effectively with pigeons. This procedure was designed by Konorski (1959) and further developed by Wasserman (1976) and Nelson and Wasserman (1978). The procedure consists of a successive presentation of a pair of stimuli (key-lights on a single key) separated by an inter-stimulus or retention interval. Reinforcement occurs following responses to the second (comparison) stimulus when this stimulus matches the first (either exactly or symbolically). No reinforcement is available on nonmatching trials. It is necessary for the organism to maintain a respresentation of the visual characteristics of the first, or sample, stimulus in memory throughout the retention interval since that stimulus is no longer physically present. This memory is then used in a decision process concerning responding to the comparison stimulus. It is possible to calculate a ratio of responses on matching trials to total responding to the second stimulus. A ratio of 1.00 indicates perfect matching performance and a ratio equalling .50 indicates random chance levels of performance (equal rates of responding on matching and nonmatching trials). Wasserman (1976), using pigeons as subjects, keypecks as responses, and red and green discriminative stimululi, reported results of 80-90% discrimination ratios, indicating definite stimulus control by the first stimulus.

Directed Forgetting in Pigeons

If there is a rehearsal process in pigeon STM, it should be possible to control the amount of rehearsal (and the corresponding retention) of stimuli in a manner analogous to the human directed forgetting studies by using cues that direct the animal to discontinue rehearsal, or "forget." Given that the DMTS procedure is an effective tool in investigating STM in pigeons it would follow that directed forgetting procedures could be incorporated into the DMTS paradigm just as they are incorporated into the Brown-Perterson paradigm in human memory research. This procedure could be used to investigate the possible use of rehearsal in the pigeon that is analogous to Type I rehearsal to maintain items beyond the normal trace life. Olton (1979) in his work with rats in radial-arm mazes foresees work in this area when he raises the question as to whether or not "resetting" (forgetting) can be placed under discriminative control.

The notion of using directed forgetting techniques in conjunction with DMTS procedures originated with a study by Maki, Gillund, Hauge and Siders (1977) on the effect of the cancellation of the comparison stimulus. Maki et al. found that when the comparison stimulus was omitted from some trials the matching accuracy on later trials was reduced to chance levels. The effect of this unsignalled cancellation of the comparison stimulus raised questions about the effects of a signalled cancellation of the comparison stimulus (directed forgetting). Maki followed this line of thought with a paper presented at the 1979 meeting of the Midwestern Psychological Convention. Maki and Anundson (Note 1), using a choice DMTS procedure, presented birds with a white center key. A single keypeck on this key produced a 2 second sample of either food or no food. After an interstimulus interval of 1.5 seconds remember (R) and forget (F) cues (.5 second flash of houselight or no flash of houselight) occurred. On R cued trials comparison stimuli of Red and Green keylights were presented after the remainder of the delay interval, which averaged 10.3 seconds. Responses to red following food samples and to green following no food samples were reinforced. Incorrect choices terminated the trial. On F cued trials comparison stimuli were not presented. Maki and Anundson ended sessions with 8 "probe" trials, during which the comparison stimuli occurred on both R cued and F cued trials. They found that choice matching performance was at 75% on F cued probe trials as compared to 91% on R cued probe trials.

An explanation for the ability to get cued forgetting in a pigeon STM procedure could be offered based on the results of human directed forgetting studies and Bjork's selective rehearsal hypothesis. It is possible that a rehearsal process was utilized by the pigeon to maintain the characteristics of the first stimulus throughout the retention interval on R cued trials. This condition was functionally the same as no cue at all, or a standard DMTS procedure. The relatively poor retention on F cued trials can be attributed to a cessation of rehearsal elicited by the forget cue at the beginning of the retention interval. This explanation is consistent with those offered in human directed forgetting studies. According to Bjork and Geiselman (1978):

> In the item-by-item cueing paradigm, one might assume that items are kept at a shallow level of processing through maintenance or primary rehearsal until the cue is presented. When a forget cue is presented, it terminates or inhibits the processing that would go on automatically without such a cue. (p. 349)

Temporal Location of the Cue

One implication of the above explanation for the directed forgetting effect is that the temporal relation of the forget cue to the TBF item is a crucial variable in determining the effectiveness of that cue. The longer the delay between the sample stimulus and the forget cue the more processing a TBF item would receive. Also, the shorter time from the F cue until the onset of the comparison, the less time there is for forgetting in the absence of rehearsal (either through decay or interference) to occur. If the superior matching performance of R cued trials over F cued trials is the result of differential amounts of rehearsal, or the result of differential amounts of time since rehearsal termination, varying the temporal location of the cue within a constant length retention interval will reduce the difference in matching performance between R and F cued conditions. In other words, delaying the cue will reduce the effectiveness of the F cue.

One would probably not predict that varying the temporal location of an R cue would have any effect on performance in pigeon directed forgetting studies. In human research, where the temporal location of an R cue does have an effect, it has been demonstrated that pre-cue rehearsal is a rote maintanance rehearsal, while post-cue rehearsal on R cued trials is a more elaborative secondary rehearsal (Bjork & Geiselman, 1978). There is no evidence for anything more than a rote maintenance rehearsal pre- or post-cue in the pigeon. Since elaborative rehearsal is closely associated with long-term memory, it is probably not a factor in this paradigm, at least according to Roberts and Grant (1976), who claim that long-term memories of events occurring in DMTS trials are not established in the pigeon. Since the directed forgetting effect in pigeons is then due solely to differential amounts of rote primary rehearsal this effect can be seen as directly analogous to recognition (but not recall) tests in human directed forgetting studies. As previously pointed out, these recognition tests are influenced by Type I, but not Type II, rehearsal (Glenberg & Adams, 1978; Glenberg, Smith and Green, 1977).

Assuming that the directed forgetting effect in pigeons is the result of differential amounts of rehearsal, (or differential amounts of lack of rehearsal) the temporal position of the F cue is a crucial variable. Based on the above model primary rehearsal occurs both before and after the cue on R trials. This rehearsal only occurs before the cue on F trials. The total rehearsal on F cued trials increases with longer delays between the sample and the cue, resulting in decreased differential rehearsal between R and F cued trials. The total time in the absence of rehearsal (the post-cue interval) decreases with longer delays between the sample and the cue (in a constant length retention interval). With an immediate cue forgetting in the absence of rehearsal occurs for the entire duration of the retention interval. The closer the onset of the F cue gets to the end of the retention interval, the less time there is for forgetting to occur before the onset of the comparison stimulus. The combined factors of more rehearsal and less forgetting should decrease the effectiveness of the F cue (i.e., the pigeon will be less able to forget on F cued trials the later the F cue occurs).

There is much support in the literature on human directed forgetting for the notion that the longer the delay between TBF items and the F cue the less effective the cue will be. Timmons (1974) designed an experiment to explore the effect of varying the amount of processing time between the presentation of a block of words and the forget cue. Timmons found that the time of cue presentation was a critical variable in the recognition of TBF items, and that when the cue is delayed until just prior to recall the TBF items received just as much processing as if no cue had been presented at all. These items were more likely to be recognized on a subsequent test than items that were not maintained in STM as long, due to earlier cueing. Reed (1970) also demonstrated that the greatest effect of a forget cue was obtained when the cue occurred at the beginning of the retention interval rather than the end.

The effect of delayed cueing has also been demonstrated in item by item cueing procedures, which more closely parallel the DMTS procedure used with pigeons. Woodward et al. (1973) felt that an item would be better remembered and less easily forgotten the greater the amount of rehearsal there was that was devoted to that item. By varying the rehearsal time between each item and its corresponding cue they established that the final recognition increased systematically with the amount of rehearsal. As previously described, Wetzel and Hunt (1977) used a between list variation of the cue location, rather than the within list variation of Woodward et al., to demonstrate the effect of amount of rehearsal on both recall recognition. The between list variation eliminated the equality of rehearsal for items that initially had different word-cue intervals. Wetzel and Hunt's study compared short and long delay cueing conditions for equal retention intervals. Their long delay condition utilized pre-cue intervals of 1, 4, 8, and 12 seconds. They clearly demonstrated that immediate cueing produced much more efficient forgetting than delayed cueing, and that this efficiency was a function of the length of the word-cue interval. Clearly the greater opportunity for rehearsal prior to the onset of the F cue decreased the ability of the subjects to forget or discard that memory. It is precisely this effect that is the main focus of the present study.

To recapitulate, it is assumed that the greater matching performance following an R cue over the performance following an F cue is due to the pigeon's ability to utilize the F cue to terminate rehearsal processes. Since R cued items are rehearsed both before and after the cue, and F cued items are rehearsed only before the cue, it is assumed that the differential performance is a function of the differential amounts of rehearsal, the differential amounts of time without rehearsal, or some combination of the two. By varying the temporal position of the cue within the retention is should be possible to control the amount of differential rehearsal and forgetting due to a variation in the pre- and post-cue intervals. Total rehearsal on F trials is varied through the variation of the pre-cue interval while total rehearsal on R cued trials remain constant. The net effect of a delayed cue should be negligible on R trials, but greater processing and less forgetting should produce increased retention on F trials, making the F cue less effective. Thus the matching performance on a delayed F trial should fall between the level on immediate F cued trials and the level on R cued trials, as a function of length of delay.

The initial phase of the present experiment replicates

Maki and Anundson's directed forgetting effect using a successive, rather than choice DMTS procedure. After demonstrating good memory on R cued trials and poor memory on the F cued trials the temporal location of the cues will be varied within the retention interval as described above. The importance of such a manipulation is twofold. In addition to investigating the effects of manipulating the cue location on matching performance this manipulation has special importance in the interpretation of the immediate cue data of both this and Maki and Anundson's experiment. In both procedures the memory on F cued trials is assessed on "probe" trials which instruct the pigeon that the comparison stimulus will not occur and then follow that cue with a comparison stimulus. If one assumes only a trace-decay model and does not allow for rehearsal processes, it might be argued that the directed forgetting effect obtained in the two studies was merely an artifact of the testing procedure used. The forgetting that is demonstrated by poorer matching performance on probe trials (F cued) could be explained by the fact that the occurrence of the comparison stimulus following a forget cue is contrary to training and is therefore disrupting. If this is the case, the forgetting could be just as easily explained as a function of retroactive interference of a passive trace (causing increased decay) as it could be termination of an active rehearsal process. The immediate cue data are confounded by the fact that both reduced rehearsal and disruption due to the conflicting occurrence of the forget cue and the comparison stimulus would produce the same behavioral results--reduced matching performance. In the present experiment, however, these two explanations are pitted against one another and the controlling variable should become clear. In the delayed cueing condition the amount of pre-cue rehearsal time is greater than the amount of pre-cue rehearsal time in the immediate cueing condition. If termination of an active maintenance process is the controlling variable in the poor matching performance on F cued trials under the immediate cueing condition, the delayed cueing condition should not produce such a poor matching performance. Matching performance should improve due to a stronger memory trace of the sample stimulus (due to either more rehearsal or less time since rehearsal terminations). In other words, the forget cue would be less effective in the delayed condition than it is in the immediate condition. If, on the other hand, disruption is the cause of poorer matching performance following an F cue one would not expect better matching performance on delayed cue trials. The poor matching performance that occurs on F cued trials when the cue is immediate should also occur when the cue is delayed because a delayed cue would be at least as disrupting as an immediate due, if not more so (cf. Roberts and Grant's 1978 work on the effect of the point of interpolation of a light within the retention interval). If disruption occurs due to an incongruent pairing of an F cue and a second stimulus, this pairing should be incongruent regardless of the temporal occurrence of the F cue, since training will occur with both immediate and delayed cueing conditions. A delayed F cue should be just as "effective" as an immediate F cue under this model. Thus the prediction of a disruption hypothesis would be equal or inferior matching performance for the delayed cueing condition as opposed to immediate cueing, while the rehearsal hypothesis would predict greater matching performance (less able to forget) in the delayed cue condition.

Pilot data from cue location manipulations have favored a rehearsal termination hypothesis. Further questions can therefor be asked regarding the factors that lead to the effectiveness of an immediate cue as opposed to the reduced effectiveness of a delayed cue. In the design of the present experiment as has been described thus far there are three variables--duration of the retention interval, duration of the pre-cue interval, and duration of the post-cue interval--that are related in such a way that only one can be held constant at a time leaving the other two variables confounded. In the experiment as described thus far the retention interval will be held constant at 4 seconds while pre-cue intervals of 0, 2, and 3.5 seconds will be paired with post-cue intervals of 3.5, 1.5, and 0 seconds respectively (the cue will be 0.5 seconds). As has been alluded to, the result is that it is unclear whether the primary influence of the expected reduced effectiveness of delayed F cues is increased rehearsal (during increased pre-cue intervals) or decreased forgetting in the absence of rehearsal through decreased post-cue intervals. In human studies it can be shown that increased rehearsal leads to better memory. In the pigeon it may be that rehearsal does not strengthen the memory trace but merely maintains in enough to postpone the occurrence of forgetting through either decay or interference. If this hypothesis is true, the critical determinant of amount of forgetting should be the amount of time from the termination of rehearsal, as controlled by the F cue, until the presentation of the comparison stimulus (the post cue interval). If amount of rehearsal is the critical determinant of the amount of forgetting the crucial variable would then be the pre-cue interval. Should the strength of the memory for the sample vary with cue location as is expected, the final phase of this experiment will be an attempt to determine which of these intervals--pre or post-cue--plays the more important role in producing this effect. This will be accomplished by varying the retention interval and comparing performance against one condition where the pre-cue interval is held constant while the post-cue varies, and against another condition where the post-cue interval is held constant and the pre-cue interval varies.

METHOD

SUBJECTS

Two adult experimentally naive White Carneaux pigeons were used. Birds were maintained at 80% ± 15 g of their free-feeding weights. Birds were individually housed in a temperature controlled and constantly illuminated room and had free access to water and grit.

APPARATUS

A standard Lehigh Valley Electronics three key conditioning chamber was used. Interior dimensions were 35 x 35 x 30 cm. Only the center 2.5 cm. response key, which required a force of 0.15 N for activation, was used. The response key was trans-illuminated with either a red (606 nm) or green (555 nm) stimulus from an IEE projector (Model # : 10-3723-757-L). The key was located above the 5 x 6 cm magazine opening. Above the key was a 28 V houselight (CM 1820). Also located on the intelligence panel was a circular speaker gril. During reinforcement a 28 V light (SYLVANIA 28 PSB) within the magazine enclosure was illuminated. Activation of a Lehigh Valley Electronics photoelectronic relay initiated the reinforcement timer. An exhaust fan, located on the wall opposite the response panel, partially masked extraneous noises. Experimental events were controlled by standard electromechanical programming equipment located in an adjacent room, with a paper tape reader controlling the sequence of events.

PROCEDURE

Both birds were trained to approach and eat mixed grain from the magazine. Birds were placed in the lighted test chamber with the magazine elevated, lighted, and food easily visible. A photoelectric beam was broken when the bird ate from the magazine, and 2.5 seconds later the magazine lowered out of reach. Thirty presentations of food occurred on a variable time schedule of 45 seconds.

For the next three sessions birds were autoshaped according to the Brown and Jenkins (1968) autoshaping procedure. Each autoshaping session consisted of 50 trials during which a six second stimulus presentation of either a red or green keylight was immediately followed by reinforcement. The mean interval was 45 seconds. Throughout the entire experiment reinforcement consisted of 2.5 seconds access to mixed grain. After three autoshaping sessions both birds were reliably pecking both red and green stimuli.

Following autoshaping birds were trained on the successive delayed matching to sample task following the procedures outlined in Table 1. The stimulus parameters followed Nelson and Wasserman (1978) to obtain maximum matching performance. Typically, the sample was presented for 12 seconds, followed by a retention interval during which no stimulus appeared until the onset of the comparison stimulus. Keypecks to the comparison stimulus when it was the same as the sample (matched) were reinforced, and keypecks during nonmatching comparison stimuli were extinguished. The intertrial interval was 30 seconds.

Table 1

Training Procedures for Phase I and the Transition Phase

Phase I: Delayed Matching to Sample Training	12 Second Sample Stimulus	Delay Interval	5 Second Comparison Stimulus
	RED	X sec.	RED: FI 5 sec.
	RED	X sec.	GREEN: extinction
	GREEN	X sec.	RED: extinction
	GREEN	X sec.	GREEN: FI 5 sec.

Transition Phase	Onset of Retention Interval		Onset of Comparison Stimulus
	12 R cues		
	24 R cues		
	36 R cues		
	36 R cues	4 F cues	
	36 R cues	8 F cues	
	36 R cues	12 F cues	
	36 R cues	20 F cues	
	36 R cues	28 F cues	
(Final Directed-Forgetting Stage)	36 R cues	36 F cues	
	36 R cues	36 F cues	Tone

From the responses to the matching and nonmatching comparison stimuli discrimination ratios were calculated as a measure of matching accuracy or performance. This ratio was calculated by dividing the responses during matching comparison stimuli by the total number of response during comparison stimuli, both matching and nonmatching. A discrimination ratio of 1.00 indicates perfect matching performance with responding during the comparison stimuli occurring exclusively on matching trials. A ratio of .50 indicates chance levels of matching performance, with equal levels of responding occurring on matching and nonmatching trials.

During training the duration of the retention interval was initially set at one second. This interval was maintained until a bird performed above an 80% discrimination ratio for two consecutive days. Retention intervals were increased in one second increments each time the above criterion was met until the terminal value of four seconds was reached. Once this level of performance was met and maintained, the introduction of remember (R) and forget (F) cues (vertical and horizontal lines presented on the key) began according to the schedule on the bottom of Table 1. During this transition phase between basic DMTS and DMTS with directed forgetting the 0.5 second cues occurred immediately after the termination of the sample stimulus. The key remained dark for the remainder of the retention interval. Cued trials were randomly interspersed among noncued trials during the transition phase. These cued trials are procedurally the same as the trials in Phase II (Table 2), with the second stimulus not occurring following a forget cue. The transition phase proceeded to the next level each time performance met the 80% discirmination ratio criterion. Once all trials were being cued, a 40 msec 1,000 Hz tone of approximately 80 db was added to the procedure. This tone occurred contiguous with the onset of the comparison stimulus as an additional cue indicating the presence of that stimulus (the importance of the tone is on F cued probe trials where after presenting the forget cue to the bird, the comparison stimulus is presented. Since birds often turned away from the key upon seeing an F cue it was necessary to alert the bird as to the presence of the comparison stimulus on those trials in order to accurately assess memory on those trials).

Table 2 outlines the procedures used in Phases II, III, IV and V. All followed the same basic procedure, with the defining characteristic of each phase being the temporal location of the cues within the retention interval. For Phase II the cues occurred immediately after the termination of the sample stimulus (0 second delay). For Phase III the 0.5 second cues occurred as late as possible within the 4 second retention intervals, in other words at a 3.5 second delay. During Phase IV cues were located in the middle of the 4 second retention interval at a 2 second delay. For Phase V the retention interval was shortened from 4 to 2.5 seconds and the cues occurred after a 2 second delay. Each of these phases is pictorially represented at the bottom of Table 2.

During training on all four phases the comparison stimulus was only presented on R cued trials. On F cued trials the retention interval was followed directly by the ITI. Training proceeded on each phase until the bird performed at or above the 80% criterion for five consecutive days. Once the criterion was met probe sessions began. For each phase five probe sessions, consisting of 68 baseline and 4 randomly located probe trials, were presented. Probe sessions that

Table 2

Training and Testing Procedures
For Phases II, III, IV, and V

Phase II: Training

S1---0.5 sec R cue---3.5 sec---S2(matching)---Rf---ITI

S1---0.5 sec R cue---3.5 sec---S2(nonmatching)---ITI

S1---0.5 sec F cue---3.5 sec--ITI

Phase II: Testing (5 sessions)

S1--0.5 sec R cue---3.5 sec---S2(matching)--Rf---ITI

S1--0.5 sec R cue---3.5 sec---S2(nonmatching)---ITI

S1--0.5 sec F cue---3.5 sec---S2(matching)--Rf---ITI

S1--0.5 sec F cue---3.5 sec--S2(nonmatching)---ITI

Phase III: Training and Testing

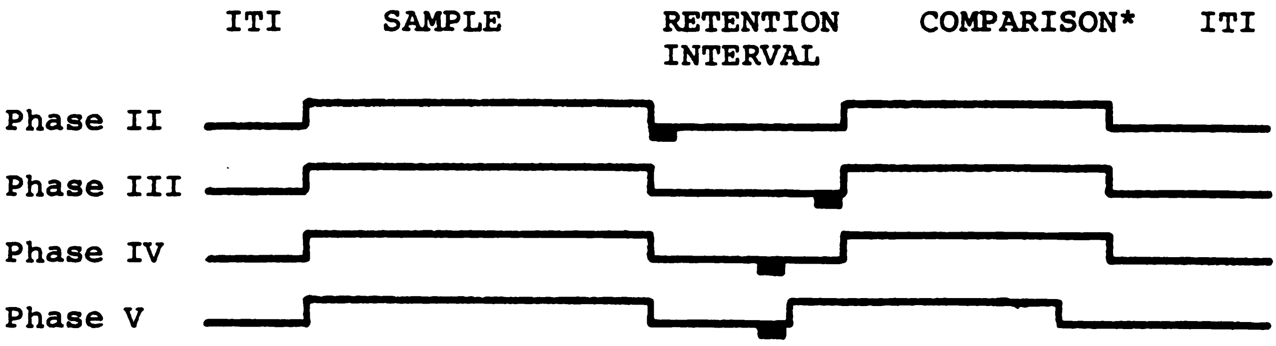
S1---3.5 sec---0.5 sec cue---S2 or ITI

Phase IV: Training and Testing

S1---2 sec---0.5 sec cue---1.5 sec---S2 or ITI

Phase V: Training and Testing

S1---2 sec---0.5 sec cue---S2 or ITI



* On R cued and Probe trials only

—■— R/F cue

failed to maintain a 75% discrimination ratio on baseline trails were eliminated from the final analysis. Probe sessions were alternated with as many sessions as were necessary to maintain the 80% discrimination ratio. After data was collected on five probe sessions the bird proceeded to training on the next phase.

On probe trials the F cue was presented and was followed by the comparison stimulus, contrary to training (see Table 2). One of each of the four combinations of red and green was used as a probe trial within a single probe session. The order of the probe trials within a session was balanced between sessions. Reinforcement was available following matching probes and extinction was in effect on nonmatching probes.

RESULTS

Table 3 shows the response rates during comparison stimuli for each bird under the various conditions. From these response rates the discrimination ratios in Figure 1 were calculated, using the formula previously described. Again, a ratio of 1.00 indicates perfect matching performance and a ratio of .50 indicates chance levels of performance. Only the discrimination ratios for the 4 second retention interval conditions (Phases II, III, and IV) are plotted on this figure. Under the 0 second delay condition it can be seen that birds 1162 and 1067 had matching accuracies of .91 and .86 respectively on R cued trials, while performance on F cued trials was greatly reduced to .58 and .54. By referring to Table 3 it can be seen that these near chance levels of performance were primarily due to increased levels of responding on nonreinforced nonmatching trials (red-green and green-red) rather than a reduction in levels of responding on reinforced matching trials (red-red and green-green).

In Figure 1 it is clear that the temporal location of an R cue had little or no effect on performance on those trials, especially for bird 1162 where all 3 cue locations produced matching accuracy of .91. The temporal location of an F cue within the retention interval substantially influenced behavior on those trials, however, as can be seen in the figure. The longer the onset of the cue was delayed the better

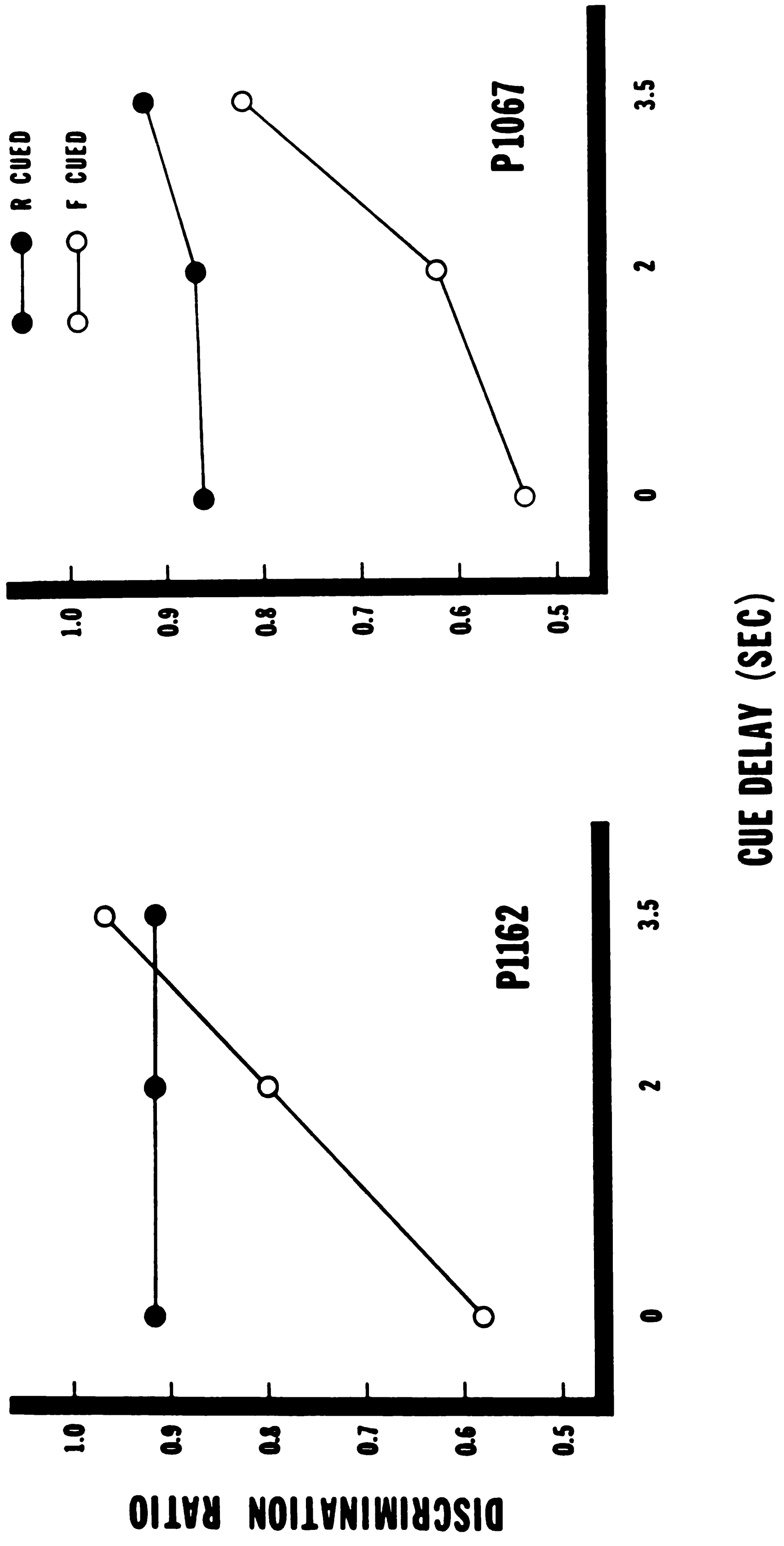
Table 3

Responses per minute during comparison stimuli following Remember (R) and Forget (F) cues during 4 and 2.5 second retention intervals with various cue delays. Trial types are red-red (RR), green-green (GG), red-green (RG) and green-red (GR).

	R Cued				F Cued			
Bird 1067	RR	GG	RG	GR	RR	GG	RG	GR
4 sec RI[a] 0 sec delay	195.3	196.5	34.2	28.8	160.8	151.2	117.6	151.2
4 sec RI 2 sec delay	249.6	247.5	53.1	19.2	237.6	204.0	81.6	187.2
4 sec RI 3.5 sec delay	281.7	248.7	17.1	24.6	276.0	201.6	31.2	74.4
2.5 sec RI 0 sec delay	262.8	260.4	12.3	12.0	230.4	232.8	28.8	57.6
Bird 1162								
4 sec RI 0 sec delay	191.7	181.2	12.9	25.2	158.4	132.0	79.2	127.2
4 sec RI 2 sec delay	142.5	111.9	10.8	12.0	158.4	98.4	43.2	19.2
4 sec. RI 3.5 sec delay	167.4	148.5	12.6	18.3	136.8	124.8	2.4	7.2
2.5 sec RI 0 sec delay	167.1	122.4	34.2	21.3	141.6	105.6	4.8	19.2

[a] RI = Retention Interval (interstimulus interval)

FIGURE 1. Matching performance as a function of cue delay on remember (R) and forget (F) cued trials.


R CUED
F CUED
P1067
P1162
DISCRIMINATION RATIO
1.0
0.9
0.8
0.7
0.6
0.5
CUE DELAY (SEC)
0
2
3.5

matching performance was that occurred on those trials. Also, the later the cue the less difference existed between R cued and F cued trials. After a delay of 3.5 second F cues almost completely lost their effectiveness, with performance on those trials highly similar to performance on R cued trials.

Figure 2 presents the mean number of keypecks each bird emitted during the retention intervals for the various cue delays and for the various combinations of red and green and of remember and forget cues. This figure presents the retention interval keypecks that occurred during the five-day baseline periods before testing on Phase II, III and IV. Mean keypecks after red and green always differed by less than one keypeck when comparing keypecks under either remember or forget conditions for any of the cue delays for each individual bird. In other words there was no difference in keypecking behavior following red and green samples. However, there are differences in the amount of keypecking that occurs on remember versus forget cued trials. These differences resulted from the fact that generally birds pecked the key during the retention interval until the presentation of the cue. If a remember cue was presented pecking continued until the presentation of the comparison stimulus. If a forget cue was presented keypecking stopped and the bird usually began engaging in other behaviors (intertrial behaviors such as exploring and preening, since an F cue indicated the end of a trial on all trials except probes). Consequently, few keypecks occurred during the retention interval when there was no delay between the end of the sample and the presentation

FIGURE 2. Mean keypecks during 4 second retention intervals as a function of cue delay and remember (R) and forget (F) cues.

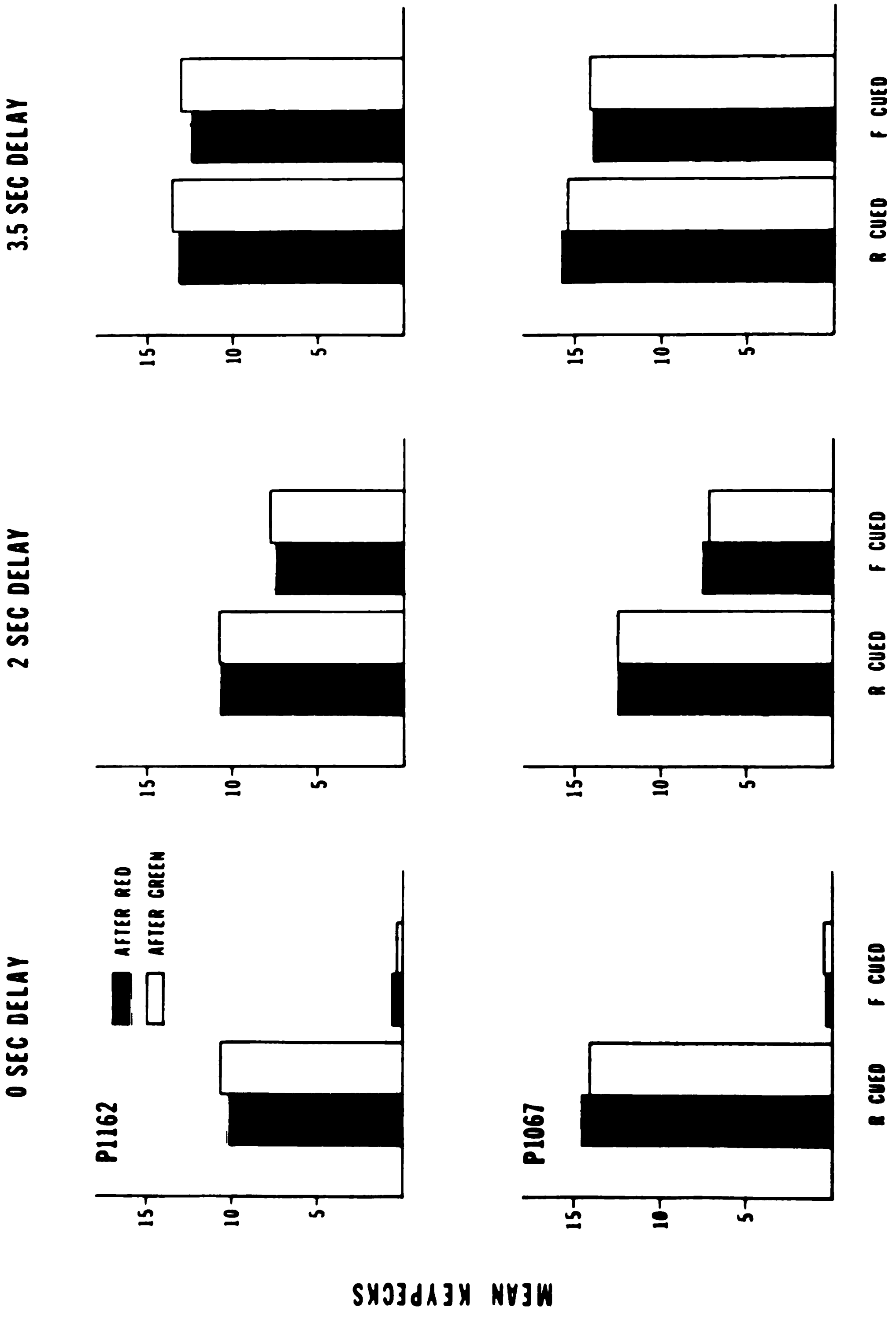
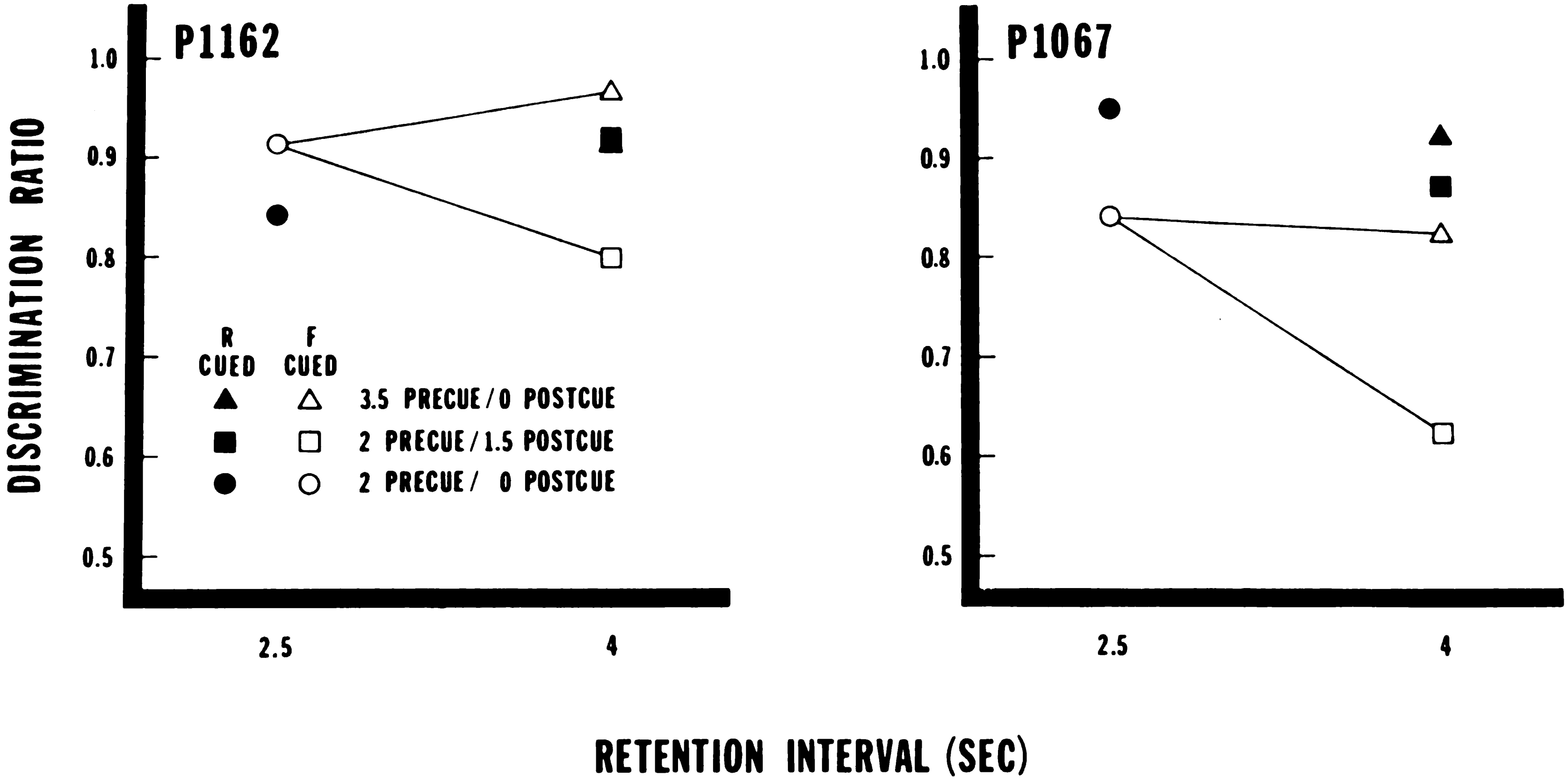

0 SEC DELAY
2 SEC DELAY
3.5 SEC DELAY
AFTER RED
AFTER GREEN
P1162
P1067
15
10
5
R CUED
F CUED
MEAN KEYPECKS

FIGURE 3. Comparison of matching performance on Phase V (control condition) to Phases III and IV.


P1162
P1067
DISCRIMINATION RATIO
1.0
0.9
0.8
0.7
0.6
0.5
R CUED
F CUED
▲ △ 3.5 PRECUE / 0 POSTCUE
■ □ 2 PRECUE / 1.5 POSTCUE
● ○ 2 PRECUE / 0 POSTCUE
2.5
4
RETENTION INTERVAL (SEC)

of an F cue, more occurred when the F cue was delayed 2 seconds, and many occurred when the cue was delayed 3 1/2 seconds. The data on the number of keypecks during the retention interval is highly similar to the matching performance depicted in Figure 1, with R cued trials remaining relatively constant and F cued trials increasing as a function of the cue delay.

Figure 3 presents the data obtained on Phase V in relation to the data obtained in Phases III and IV. The latter data, from conditions with 4 second retention intervals and 2 and 3.5 second cue delays respectively, is the exact same data from those cue delays on Figure 1. The new point of interest is that from Phase V, where the retention interval is 2.5 seconds and the cue delay is 2 seconds. By varying the retention interval in this fashion it is possible to compare the Phase V point with each of the other points. In comparing the Phase V point with the 3.5 second delay point the post-cue interval is held constant at 0 seconds while the pre-cue interval is increased from 2 to 3.5 seconds. In comparing the Phase V point with the 2 second delay point the pre-cue interval is held constant at 2 seconds and the post-cue interval is increased from 0 to 1.5 seconds. For both birds it can be seen that the former comparison, increasing the pre-cue interval, had very little effect on matching performance (.84 vs. .82 for bird #1067; .91 vs. .96 for bird #1162). On the other hand, the latter comparison, which increases the post-cue interval, clearly demonstrates that with a longer period from the end of an F cue until the presentation of the comparison matching performance sharply declines, even at a difference of only 1.5 seconds (.84 vs. .62 for bird # 1067; .91 vs. 80 for bird #1162).

DISCUSSION

The results of this experiment present extremely strong evidence in favor of an active memory processing in the pigeon. If short-term memory in the pigeon is a passive process that is not under the control of the organism, remember and forget cues could not gain stimulus control. Therefore, performance with immediate cues should be similar for both remember and forget cued trials. The data obtained with immediate cues in Figure 1 are extremely consistent with Maki's directed forgetting results in that matching performance is very good on remember cued trials and greatly reduced on forget cued trials, supporting an active processing hypothesis. The results with delayed cues, in that a delayed F cue is less effective the later it occurs within the retention interval, demonstrate that the effect with immediate cues is due to different memory strengths on R and F cued trials that seems to have resulted from differential rehearsal. Apparently when an R cue is presented the pigeon rehearses during the entire retention interval, both before and after the cue regardless of its temporal location. On F cued trials it appears as if the pigeon rehearses until the F cue is presented, and terminates rehearsal upon the presentation of that stimulus. This behavior closely parallels the behavior reported in human directed forgetting studies by Bjork and Geiselman (1978) and others.

The notion that the immediate cue data in this and in

Maki's study could be due to a disruption caused by the testing procedure is clearly not supported. Such a hypothesis would predict equal disruption regardless of the temporal location of an F cue. This is clearly not the case. Rather, F cues lose their effectiveness when they are delayed within the retention interval to the point where a cue at the end of the retention interval is barely different from R cued trials, if at all. This appears to be due to the changes in differential rehearsal. The less a stimulus is maintained via rehearsal during the retention interval, the poorer the memory for that stimulus will be at the end of the retention interval.

The results presented in Figure 2 show that when pigeons rehearsed during the retention interval they also keypecked. This data would not lead one to conclude that keypecking was the rehearsal process, however, in light of the fact that keypecking was nondifferential following red and green sample stimuli. However, it is more likely that keypecking is a collateral behavior occurring simultaneously with rehearsal. If this is the case it is easier to think of rehearsal as a cognitive process, since the maintenance of two behaviors--one sample specific and one nondifferential--does not seem parsimonious. In observing the behavior of birds during the retention interval it was noted that birds stayed focused on the key (usually keypecking) for the entire retention interval on R cued trials. The consistently high matching performance on R cued trials indicates that rehearsal was maintained throughout the retention intervals on those trials. On F cued trials birds stayed at the key only until the cue. When an F cue was presented birds not only stopped keypecking but also left the key and began other behaviors that proved to interfere with the memory of the sample stimulus. The function of matching performance on F cued trials indicates that rehearsal occurred for increasing periods of time as a function of cue delay, probably during the pre-cue interval. It is my opinion, then, that during the time attention was focused on the key a cognitive rehearsal process was occurring. Attention was focused on the key in order to reduce interference from other stimuli and events. As attention was focused on the key during rehearsal the natural response of the pigeon was to peck the key, but that keypecking behavior was not itself the rehearsal process. Whether keypecking was necessary or whether focused attention alone would have been sufficient to reduce interfering events is not clear.

In saying that the results of Figure 1 are due to varying amounts of differential rehearsal it should be noted that implied in this term are two contributing factors: differential amounts of time when rehearsal was occurring and differential amounts of time when rehearsal was not occurring. On F cued trials the former relates to the pre-cue interval and the latter relates to the post-cue interval. The results in Figure 3 show which of these factors played the major role in F cues becoming less effective as cue delay increases. If increasing the pre-cue interval produced the decreasing effectiveness of the F cues one would predict that the new point on the left from Phase V (2.5 second retention interval) would be similar to the lower of the two points on the right and different from the higher of the two points. This prediction stems from the fact that in the former comparison the pre-cue interval is held constant whereas in the latter comparison the pre-cue interval is varied. If decreasing the post-cue interval produced the decreasing effectiveness of the F cues one would predict the opposite results; that the new point would be similar to the higher of the two points on the right and different from the lower point, since the former comparison holds the post-cue interval constant while the latter comparison varies the post-cue interval. Figure 3 indicates that performance on Phase V was more similar to the higher of the two points on the right than it was to the lower. For both birds it can be seen that increasing the amount of rehearsal (pre-cue interval) from 2 to 3.5 seconds had very little effect on memory as measured by matching performance. In contrast, increasing the amount of time after the termination of rehearsal (post-cue interval) from 0 to 1.5 seconds had a large effect on memory. Longer periods of time without rehearsal resulted in weaker memory at the time of testing. In other words the factor that produced reduced F cue effectiveness for delay cues was reduced post-cue intervals, or time since the termination of rehearsal, rather than increased rehearsal.

The result that increased rehearsal does not increase the strength of the memory is one point where the present study differs from the results found in human memory processing studies. The findings of Glenberg, Smith and Green (1977), Meunier, Ritz and Meunier (1972), Woodward et al. (1973), and Wetzel and Hunt (1977) demonstrated that there was a direct relationship between amount of Type I or maintenance rehearsal and performance on a recognition test. In pigeons it appears that the rehearsal process does not strengthen the memory trace but merely maintains it enough to postpone the occurrence of forgetting. The fact that birds are only able to maintain a memory for 4-6 seconds under the present experimental condition seems to indicate that memory loss is even occurring during the rehearsal process. Rehearsal in the pigeon therefore serves to delay or slow down the forgetting that inevitably occurs. This forgetting occurs despite rehearsal processes, but would occur much more rapidly without rehearsal.

LIST OF REFERENCES

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Atkinson, R.C., & Shiffrin, R.M. Human Memory: A proposed system and its control processes. In K.W. Spence & J.T. Spence (Eds.), The psychology of learning and motivation (Vol. 2). New York: Academic Press, 1968.

Baddeley, A.D. The trouble with levels: A reexamination of Craik and Lockhart's framework for memory research. Psychological Review, 1978, 85, 139-152.

Bjork, R.A. Positive forgetting: The non-interference of items intentionally forgotten. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 255-268.

Bjork, R.A. Theoretical implications of directed forgetting. In A.W. Melton & E. Martin (Eds.), Coding processes in human memory. Washington, D.C.: Winston, 1972.

Bjork, R.A., & Geiselman, R.E. Constituent processes in the differentiation of items in memory. Journal of Experimental Psychology: Human Learning and Memory, 1978, 4, 347-361.

Bjork, R.A., LaBerge, D., & Legrand, R. The modification of short-term memory through instructions to forget. Psychonomic Science, 1968, 10, 55-56.

Block, R.A. Effects of instructions to forget in short-term memory. Journal of Experimental Psychology, 1971, 89, 1-9.

Blough, D.S. Delayed matching in the pigeon. Journal of the Experimental Analysis of Behavior, 1959, 2, 151-160.

Brown, J. Some tests of a decay theory of immediate memory. Quarterly Journal of Experimental Psychology, 1958, 10, 12-21.

Brown, P.L., & Jenkins, H.M. Autoshaping of the pigeon's key-peck. Journal of the Experimental Analysis of Behavior, 1968, 11, 1-8.

Craik, F.I.M., & Lockhart, R.S. Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 671-684.

Craik, F.I.M., & Watkins, M.J. The role of rehearsal in short-term memory. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 599-607.

Davis, J.C. II, & Okada, R. Recognition and recall of positively forgotten items. Journal of Experimental Psychology, 1971, 89, 181-186.

Elmes, D.G., Adams, C., & Reodiger, H.L. Cued forgetting in short-term memory: Response selection. Journal of Experimental Psychology, 1970, 86, 103-107.

Epstein, W. Facilitation of retrieval resulting from post-input exclusion of part of the input. Journal of Experimental Psychology, 1970, 86, 190-195.

Epstein, W. Mechanisms of directed forgetting. In C.H. Bower (Ed.), The psychology of learning and motivation (Vol.6). New York: Academic Press, 1972.

Epstein, W., Massaro, D.W., & Wilder, L. Selective search in directed forgetting. Journal of Experimental Psychology, 1972, 94, 18-24.

Fowler, H. Cognitive associations as evident in the blocking effects of response-contingent CSs. In S.H. Hulse, H. Fowler, & W.K. Honig (Eds.), Cognitive processes in animal behavior. Hillsdale, NJ: Lawrence Erlbaum Associates, 1978.

Glanzer, M., & Meinzer, A. The effects of intralist activity on free recall. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 928-935.

Glenberg, A., & Adams, F. Type I rehearsal and recognition. Journal of Verbal Learning and Verbal Behavior, 1978, 17, 455-463.

Glenberg, A., Smith, S.M., & Green, C. Type I rehearsal: Maintenance and more. Journal of Verbal Learning and Verbal Behavior, 1977, 16, 339-352.

Grant, D.S., & Roberts, W.A. Trace interaction in pigeon short-term memory. Journal of Experimental Psychology, 1973, 101, 21-29.

Honig, W.K. On the conceptual nature of cognitive terms: An initial essay. In S.H. Hulse, H. Fowler, & W.K. Honig (Eds.), Cognitive processes in animal behavior, Hillsdale, NJ: Lawrence Erlbaum Associates, 1978.

Hunter, W.S. The delayed reaction in animals and children. Behavior Monograms, 1913, 2, 1-86.

James, W. *The principles of psychology* (Vols. 1 & 2). New York: Holt, 1890.

Jongeward, R.H., Woodward, A.E., & Bjork, R.A. The relative roles of input and output mechanisms in directed forgetting. *Memory and Cognition*, 1975, *3*, 51-57.

Konorski, J. A new method of physiological investigation of recent memory in animals. *Bulletin of the Polish Academy of Sciences*, 1959, *7*, 115-117.

Maki, W.S. & Anundson, D.K. *Stimulus control of rehearsal in pigeons: An analogue of directed forgetting*. Paper presented at the meeting of the Midwestern Psychological Association, Chicago, May, 1979.

Maki, W.S., Gillund, G., Hauge, G., & Siders, W.A. Matching to sample after extinction of observing responses. *Journal of Experimental Psychology: Animal Behavior Processes*, 1977, *3*, 285-296.

Medin, D.L. Animal models and memory models. In D.L. Medin, W.A. Roberts, & R.T. Davis (Eds.), *Processes of Animal Memory*, Hillsdale, NJ: Lawrence Erlbaum Associates, 1976.

Meunier, G.F., Ritz, D., & Meunier, J.A. Rehearsal of individual items in short-term memory. *Journal of Experimental Psychology*, 1972, *95*, 465-467.

Neisser, U. *Cognitive psychology*. New York: Appleton-Century-Crofts, 1967.

Nelson, K.R., & Wasserman, E.A. Temporal factors influencing the pigeon's successive matching-to-sample performance: Sample duration, intertrial interval, and retention interval. *Journal of the Experimental Analysis of Behavior*, 1978, *30*, 153-162.

Olton, D.S., Characteristics of spatial memory. In S.H. Hulse, H. Fowler, & W.K. Honig (Eds.), *Cognitive processes in animal behavior*, Hillsdale, NJ: Lawrence Erlbaum Associates, 1978.

Olton, D.S. Mazes, maps, and memory. *American Psychologist*, 1979, *3*, 583-596.

Peterson, L.R., & Peterson, M.J. Short-term retention of individual verbal items. *Journal of Experimental Psychology*, 1959, *58*, 193-198.

Reed, H. Studies of the interference process in short-term memory. *Journal of Experimental Psychology*, 1970, *84*, 452-457.

Reynolds, A.G., & Flagg, P.W. Cognitive psychology. Cambridge, Massachusetts: Winthrop, 1977.

Roberts, W.A. Short-term memory in the pigeon: Effects of repetition and spacing. Journal of Experimental Psychology, 1972, 94, 74-83.

Roberts, W.A. & Grant, D.S. Short-term memory in the pigeon with presentation time precisely controlled. Learning and Motivation, 1974, 5, 393-408.

Roberts, W.A., & Grant, D.S. Studies of short-term memory in the pigeon using the delayed matching-to-sample procedure. In D.L. Medin, W.A. Roberts, & R.T. Davis (Eds.), Processes of animal memory. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976, 79-112.

Roberts, W.A., & Grant, D.S. An analysis of light-induced retroactive inhibition in pigeon short-term memory. Journal of Experimental Psychology: Animal Behavior Processes, 1978, 4, 219-236.

Rundus, D. Maintenance rehearsal and single-cued processing. Journal of Verbal Learning and Verbal Behavior, 1977, 16, 665-681.

Shebilske, W., Wilder, L., & Epstein, W. Forget instructions: The effect of selective rehearsal and categorical distinctiveness. Journal of Experimental Psychology, 1971, 89, 372-378.

Shimp, C.P., & Moffitt, M. Short-term memory in the pigeon: Stimulus-response associations. Journal of the Experimental Analysis of Behavior, 1974, 22, 507-512.

Terry, W.S., & Wagner, A.R. Short-term memory for "surprising" vs. "expected" unconditional stimuli in Pavlovian conditioning. Journal of Experimental Psychology: Animal Behavior Processes, 1975, 1, 122-133.

Timmins, W.K. Varying processing time in directed forgetting. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 539-544.

Tulving, E. Subjective organization and effects of repetition in multitrial free-recall learning. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 193-197.

Tulving, E., & Colotla, V. Free recall of trilingual lists. Cognitive psychology, 1970, 1, 86-98.

Underwood, B.J. Are we overloading memory? In A.W. Melton & E. Martin (Eds.), Coding processes in human memory. Washington, D.C.: Winston, 1972.

Wagner, A.R. Priming in STM: An information processing mechanism for self-generated or retrieval generated depression in performance. In T.J. Tighe & R.N. Leaton (Eds.), Habituation: Perspectives from child development, animal behavior, and neurophysiology. Hillsdale, NJ: Lawrence Erlbaum, 1976.

Wagner, A.R., Rudy, J.W., & Whitlow, J.W. Rehearsal in animal conditioning. Journal of Experimental Psychology Monograph, 1973, 97, 407-426.

Wasserman, E.A. Successive matching-to-sample in the pigeon: Variations on a theme by Konorski. Behavior Research Methods and Instrumentation, 1976, 8, 278-282.

Waugh, N.C., & Norman, D.A. Primary memory. Psychological Review, 1965, 72, 89-104.

Wetzel, C.D. Effect of orienting tasks and cue timing on the free recall of remember- and forget-cued words. Journal of Experimental Psychology: Human Learning and Memory, 1975, 1, 556-566.

Wetzel, C.D., & Hunt, R.E. Cue delay and the role of rehearsal in directed forgetting. Journal of Experimental Psychology: Human Learning and Memory, 1977, 3, 233-245.

Woodward, A.W., & Bjork, R.A. Forgetting and remembering in free recall: Intentional and unintentional. Journal of Experimental Psychology, 1971, 89, 109-116.

Woodward, A.E., Bjork, R.A., & Jongeward, R.H. Recall and recognition as a function of primary rehearsal. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 608-617.

Woodward, A.E., Park, D.C., & Seebohm, K. Directed forgetting as a function of explicit within-list cueing and implicit post-list cueing. Journal of Experimental Psychology, 1974, 102, 10001-10006.

Zentall, T.R. Memory in the pigeon: Retroactive inhibition in a delayed matching task. Bulletin of the Psychonomic Society, 1973, 1, 126-128.

Zentall, T.R., Hogan, D.E., Howard, M.M., & Moore, B.S. Delayed matching in the pigeon: Effect on performance of sample specific observing responses and differential delay behavior. Learning and Motivation, 1978, 9, 202-218.