

MOST DIRECTED FORGETTING IN PIGEONS CAN BE ATTRIBUTED TO THE ABSENCE OF REINFORCEMENT ON FORGET TRIALS DURING TRAINING OR TO OTHER PROCEDURAL ARTIFACTS

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In research on directed forgetting in pigeons using delayed matching procedures, remember cues, presented in the delay interval between sample and comparisons, have been followed by comparisons (i.e., a memory test), whereas forget cues have been followed by one of a number of different sample-independent events. The source of directed forgetting in delayed matching to sample in pigeons was examined in a 2×2 design by independently manipulating whether or not forget-cue trials in training ended with reinforcement and whether or not forget-cue trials in training included a simultaneous discrimination (involving stimuli other than those used in the matching task). Results were consistent with the hypothesis that reinforced responding following forget cues is sufficient to eliminate performance deficits on forget-cue probe trials. Only when reinforcement was omitted on forget-cue trials in training (whether a discrimination was required or not) was there a decrement in accuracy on forget-cue probe trials. When reinforcement is present, however, the pattern of responding established during and following a forget cue in training may also play a role in the directed forgetting effect. These findings support the view that much of the evidence for directed forgetting using matching procedures may result from motivational and behavioral artifacts rather than the loss of memory.

Key words: directed forgetting, memory, delayed matching to sample, key peck, pigeons

Directed forgetting can best be described as a decrement in performance on a memory test that is attributable to instructions indicating that presented items will not be tested. In research on this phenomenon with humans, some items are followed by instructions to remember, whereas others are followed by instructions to forget. It has generally been found that memory for to-be-forgotten items is poorer than memory for to-be-remembered items (see Johnson, 1994, for a review).

In research with nonhuman animals, variants of delayed matching to sample (DMTS) have been used as analogues of directed-forgetting tasks with humans. In the most typical version of this task (e.g., Kendrick, Rilling, & Stonebraker, 1981, Experiment 1, Condition B), pigeons are trained in a three-key operant conditioning chamber to peck the comparison stimulus (presented on the left and right keys) that matches the sample (presented on the center key). For example, if the sample is red, responses to the red comparison are reinforced; if the sample is green, responses to the green

comparison are reinforced. Once a high level of performance is achieved with delays between the offset of the sample and onset of the comparisons, delay-cue training begins. In delay-cue training, half of the trials involve a remember cue (e.g., a vertical line) presented on the center key during the delay, followed by comparison stimuli. On the remaining trials, a forget cue (e.g., a horizontal line) is presented on the center key during the delay, and no comparisons are presented. Instead, the intertrial interval (ITI) follows the forget cue (a so-called omission procedure). It is assumed that during delay-cue training, the "meaning" of the forget cue is acquired (i.e., the animal learns that the forget cue signals the absence of a memory test).

Evidence of directed forgetting is inferred from poor performance on occasionally presented forget-cue probe trials, during which the forget cue is followed by red and green comparisons and correct matches are reinforced (i.e., the pigeon's memory is tested). The finding of directed forgetting in pigeons has been taken as evidence that memory is an active process involving rehearsal-like activity that can be turned on and off (e.g., Grant, 1981; Kendrick & Rilling, 1986; Maki, 1981).

It is important to note, however, that with omission procedures, presentation of a forget cue in training signals not only the absence of a memory test but also the absence of rein-

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forcement on that trial. A cue signaling the absence of reinforcement (a negative conditioned stimulus; CS-) can have a number of nonmemorial effects on behavior. First, it can result in emotional behavior (see, e.g., Terrace, 1972, in which behavior during regular discrimination learning is compared with behavior during errorless learning) that could interfere with performance of the matching task on probe trials. Second, it can result in the pigeon being unprepared to respond to the comparison stimuli on probe trials because in training, no responding is required following the forget cue. More specifically, in training, upon presentation of the forget cue the pigeon may orient away from the response panel. Not being oriented toward the comparison stimuli when they are presented on probe trials may result in an increase in response latency, effectively increasing the retention interval on forget-cue probe trials. In fact, Maki, Olson, and Rego (1981) have reported comparison choice latencies on forget-cue probe trials that were about 0.5 s longer than on remember-cue trials. On the other hand, the increase in effective retention interval on forget-cue probe trials may be insufficient to account for the performance decrement typically found on those trials (Maki *et al.*, 1981, Note 2).

One means of controlling for nonmemorial (i.e., motivational and behavioral) artifacts in research on directed forgetting in pigeons (see Roper & Zentall, 1993) is to present a simple simultaneous discrimination involving unrelated stimuli on forget-cue trials instead of the comparison stimuli that would normally be presented on remember-cue trials. Thus, for example, if the matching task involved hue samples and comparisons, forget cues in training might be followed by a choice involving a square versus an X, and (independent of the sample) responses to the X would always be reinforced. In this substitution procedure, the instructional function of the forget cue should be comparable to that of forget cues in omission procedures, because in neither case are forget cues followed by a test of sample memory. When forget cues have been followed by a substituted, simultaneous discrimination in directed forgetting experiments using two-choice DMTS, however, little evidence of disrupted matching performance has been found on forget-cue probe trials (Kendrick *et al.*, 1981, Experiment 1; Maki & Hegvik, 1980; Maki *et al.*, 1981).

Thus, the most parsimonious interpretation of these findings is that the performance disruption found on forget-cue probe trials when omission procedures have been used is produced by motivational or behavioral artifacts. When the pigeons are trained to associate the forget cue with the opportunity for reinforcement and a choice between the left and right keys can be anticipated, these artifacts are eliminated and high levels of performance are found on forget-cue probe trials.

Kendrick and Rilling (1986) have interpreted these data differently. In their view, the directed forgetting effect results not from the termination of rehearsal induced by the forget cue but from a retrieval failure at the time of the test. According to Kendrick and Rilling, once a response decision is made, memory search should be terminated. Thus, when the omission procedure is used, presentation of a forget cue terminates memory search because, in this case, a response decision (i.e., to make no response) has been made. When the substitution procedure is used, however, presentation of a forget cue does not terminate memory search, because a response decision (i.e., which side key to peck) cannot be made until the simple simultaneous discrimination is presented. Thus, according to Kendrick and Rilling, it is not the relevance of the sample that is important in maintaining or retrieving memory; rather, it is the time at which a response decision can be made. This hypothesis requires the assumption that sample memories are maintained until they can be translated into response intentions (i.e., to peck or not to peck) and are independent of the relevance of sample to comparison choice.

Roper and Zentall (1993) have proposed a different account of the absence of directed forgetting with this substitution procedure. According to Roper and Zentall, disrupted matching performance on forget-cue probe trials may result from an incompatibility between the response required following a forget cue and that required following a remember cue. The rationale is that on forget-cue probe trials, the animal is prepared to make a post-forget-cue response but instead is required to make a post-remember-cue response. Thus, with the omission procedure, the absence of a response following a forget cue is incompatible with comparison choice following a remember cue, so performance disruption on forget-cue probe trials is found. On the other hand, with the

Delay-cue training

	No discrimination	Discrimination
No Reinforcement	<u>Omission group</u> forget cue followed by intertrial interval	<u>Discrimination group</u> discrimination but no food reinforcement
Reinforcement	<u>Reinforcement group</u> single stimulus and reinforcement	<u>Substitution group</u> discrimination and reinforcement

Fig. 1. Design of experiment. Pigeons in all groups were first trained on 0-s delayed matching followed by mixed-delayed matching. Following delay-cue training, all pigeons were given four extra trials per session in which the forget cue was followed by a choice of red and green comparisons and reinforcement was provided for a response to the comparison that matched the sample.

substitution procedure, choice of the correct side key following a forget cue is quite compatible with choice of the correct comparison stimulus following a remember cue, so no performance disruption is found.

The purpose of the present experiment was to distinguish between a reinforcement account and response-based (i.e., response decision or response compatibility) accounts of the difference between forget-cue probe trial results when omission versus substitution procedures are used. To accomplish this, four groups were trained on choice DMTS involving red and green samples and comparisons. When a high level of performance was achieved with a 4-s delay between sample offset and comparison onset, remember and forget cues were introduced during the delay interval.

For all groups, remember cues, but not forget cues, were followed by a memory test (i.e., red vs. green comparisons with reinforcement provided for correct matches). Probe trials, involving forget cues followed by the memory test, were also the same for all groups. What distinguished the four groups were the events that followed the forget cues during training.

For the omission group (omission of end-of-trial events), forget cues were followed by the ITI. For the substitution group, forget cues

were followed by a simple simultaneous discrimination that was substituted for the comparison stimuli: A single response to the positive stimulus was followed by reinforcement and the ITI, whereas a single response to the negative stimulus was followed by the ITI alone. For the reinforcement group, forget cues were followed by a single stimulus presented on either the left or the right key: A single response to the stimulus was followed by reinforcement. Thus, for the reinforcement group, forget cues were associated with reinforcement but not with a side-key discrimination. For the discrimination group, forget cues were followed by a simple simultaneous discrimination and a single response to the "correct" stimulus was followed by the ITI (but no reinforcement), whereas five responses were required to the "incorrect" stimulus to initiate the ITI. Thus, for the discrimination group, forget cues were associated with a side-key discrimination but not with food presentation. The design of the experiment is presented in Figure 1.

According to a reinforcement-based theory, only the two groups that did not experience reinforcement following forget cues in training (discrimination and omission groups) should show evidence of disrupted performance on

forget-cue probe trials. According to a reinforcement-based theory, however, only the two groups that did not experience a discrimination following forget cues in training (omission and reinforcement groups) should show evidence of disrupted performance on forget-cue probe trials.

In the event that both reinforcement and discrimination contribute to the absence of performance disruption on forget-cue probe trials, the main effects of both reinforcement and discrimination on forget-cue probe trial performance might be significant. Alternatively, either reinforcement or a discrimination following the forget cue in training may be sufficient to eliminate performance disruption on forget-cue probe trials, in which case disrupted performance on forget-cue probe trials would be found only for the omission group. Finally, both reinforcement and discrimination following the forget cue in training may be necessary to eliminate performance disruption on forget-cue probe trials, in which case the absence of disrupted performance on forget-cue probe trials would be found only for the substitution group.

METHOD

Subjects

The subjects were 16 White Carneau pigeons, between 5 and 8 years old, purchased from the Palmetto Pigeon Plant. All subjects had served in an experiment in which they acquired a many-to-one symbolic-matching task involving hue and line samples and shape comparisons. The pigeons were housed in individual wire cages with free access to water and grit. They were maintained at 75% to 80% of their free-feeding body weights. The air-conditioned colony room in which they were housed was maintained on a 12:12 hr light/dark cycle.

Apparatus

The experiment was conducted in a sound-attenuating test chamber equipped with a three-key response panel. The pigeons' compartment measured 33 cm high by 31 cm wide by 35 cm across the response panel. The three rectangular pecking keys (each 3.0 cm wide by 2.5 cm high) were mounted side by side (0.5 cm apart) on the panel, with their bottom edges 21.0 cm from the wire mesh floor. Behind each key was an inline projector (Indus-

trial Electronics Engineering, Series 10, with No. 1820 lamps) that projected red (R) or green (G) hues (Kodak Wratten filter Nos. 26 and 60, respectively) on each of the three keys, three white vertical (V) or horizontal (H) lines (each 13 mm long by 3 mm wide and separated by 3 mm) on the center key, and a line drawn square (S, 13 mm on a side with lines 2 mm wide) and an X (consisting of diagonal lines, each 13 mm long and 3 mm wide) on each of the side keys. Access to a rear-mounted grain feeder filled with Purina® Pro Grains was through a horizontally centered aperture (6.0 cm by 5.0 cm) located midway between the bottom of the pecking keys and the floor. A feeder lamp (No. 1820) was lit whenever the feeder was raised. A shielded houselight located 5.0 cm above the top of the center key provided general chamber illumination. White noise at 72 dB and an exhaust fan provided sound masking. The experiment was controlled by a microcomputer located in an adjacent room.

Procedure

Delayed-matching training. Because all the pigeons were experienced with the general matching procedure (although not with this identity-matching task), no pretraining was necessary. Each pigeon began delayed-matching training with 0-s delays. Each trial began with the presentation of a red (R) or green (G) sample on the center key. Ten pecks to the sample resulted in sample offset and comparison onset (R on one side key, G on the other). For all pigeons, responses to the R comparison were reinforced following an R sample, as were responses to the G comparison following a G sample. Responses to the alternative comparison were not reinforced. All comparison responses also turned off the comparison stimuli and started a 10-s ITI. Order of sample presentation and correct comparison location was random, with the constraint that a maximum of three of each could occur in a row and an equal number of each trial type occurred in each 96-trial session. Sessions were conducted 6 days a week.

Each pigeon was trained on this task to a performance criterion of two successive sessions at 90% correct or better. It was then transferred to a mixed-delay task involving an equal number of trials with delays of 0, 1, 2, and 4 s. Training with mixed delays was continued until the pigeon attained a performance

criterion of two consecutive sessions with 21 correct (87.5% correct) or better out of the 24 trials at the 4-s delay. All pigeons were then given an additional five sessions of training.

Delay-cue training. On the following day, delay-cue training began. During delay-cue training, all trials involved a fixed 4-s delay. On half of the delay-cue trials, V was presented on the center key throughout the delay. On the remaining trials, the delay cue was H. For half of the pigeons in each group, trials with V as the delay cue were followed by R and G comparisons (i.e., V was the remember cue), whereas trials with H were not (i.e., H was the forget cue). For the remaining pigeons, V served as the forget cue and H as the remember cue.

For pigeons in the omission group, the forget cue was followed immediately by the ITI. For pigeons in the substitution group, the forget cue was followed immediately by presentation of a simple simultaneous discrimination between S and X on the side keys. On half of the trials, X was on the left. On the remaining trials, it was on the right. A single response to X was reinforced, turned off the side keys, and started the ITI. A single response to S merely turned off the side keys and started the ITI. For pigeons in the reinforcement group, the forget cue was followed immediately by presentation of X on one of the side keys (on the left on half of the trials; on the right on the remaining trials). A single response to X turned off the side keys and produced reinforcement followed by the ITI. For pigeons in the discrimination group, the forget cue was followed immediately by presentation of a simple simultaneous discrimination between S and X on the side keys. On half of the trials, X was on the left. On the remaining trials, it was on the right. A single response to X turned off the side keys and started the ITI. A single response to S, on the other hand, turned X off on the other side key, and four additional responses to S were required to turn it off and start the ITI. In neither case was food reinforcement provided.

Delay-cue training continued to a criterion of two successive sessions of 38 correct (out of 48 trials) on remember-cue matching trials. In addition, for the substitution and discrimination groups, a similar criterion was involved on forget-cue discrimination trials. For all groups, regardless of level of performance, pigeons were maintained on delay-cue training

for a minimum of 25 sessions. Pigeons that did not reach criterion in 150 sessions were dropped from the study.

Probe-trial testing phase. During probe-trial testing, all sessions included four additional (probe) trials. In all other respects, probe sessions were identical to delay-cue sessions. Probe trials involved presentation of the forget cue during the delay followed by R and G comparisons. Each probe session included one of each matching trial type (an R or G sample, with the matching comparison on the left or the right). Matching contingencies were in effect on probe trials. There were a total of 25 probe sessions. Numbers of pecks to the remember and forget cues were also collected during testing.

RESULTS

Delayed-matching acquisition. Pigeons acquired the 0-s delayed-matching task to criterion in an average of 10.9 sessions and the mixed-delay matching task to criterion in an average of 25.8 additional sessions. One-way analyses of variance (ANOVAs) performed on these data indicated that in neither case did the rate of acquisition differ significantly among the groups, both $F_s < 1$.

Delay-cue training. All but 3 pigeons reached the delay-cue training performance criterion within 68 sessions ($M = 33.2$). All 3 of the nonlearners failed to recover performance on remember-cue trials within 150 sessions and were dropped from the study. Interestingly, all 3 pigeons were from the reinforcement group. The remaining pigeon in that group reached criterion in 23 sessions. We will return to this anomalous and interesting finding in the Discussion section. Pigeons in the omission, substitution, and discrimination groups reached criterion performance at comparable rates ($M = 30.2, 31.8, \text{ and } 40.0$ sessions, respectively), $F < 1$.

Probe-trial testing. Performance on remember-cue trials during probe-trial testing remained reasonably high for all groups except the omission group. In this group the performance of 2 of the 4 pigeons (O3 and O4) on remember-cue trials fell below 70% correct. For the 2 pigeons in the omission group that maintained a relatively high level of remember-cue trial performance (O1 and O2), there was a substantial drop in performance on forget-cue probe trials (16.1% and 24.6% correct,

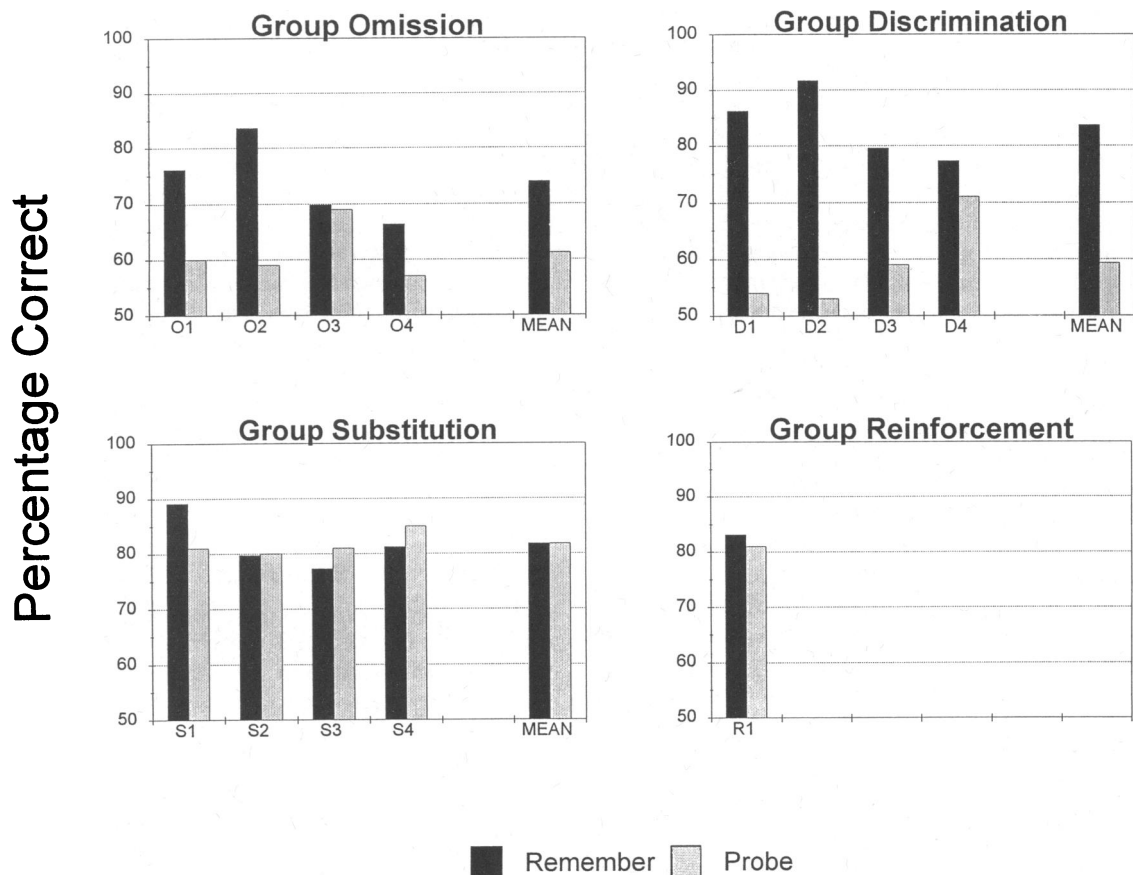


Fig. 2. Performances on remember-cue trials and forget-cue probe trials in test sessions for each tested pigeon and mean performance for each group (indicated on the abscissa). During training, forget cues were followed by the intertrial interval for the omission group (top left), by a simultaneous discrimination but no food reinforcement for the discrimination group (top right), by a simultaneous discrimination with reinforcement for the substitution group (bottom left), and by a single stimulus with reinforcement for the reinforcement group (bottom right).

respectively). The data from the omission group appear in the top left panel of Figure 2.

The pigeons in the discrimination group also showed a relatively large disruption of performance on forget-cue probe trials compared to remember-cue trials. Although the mean performance disruption appears to be somewhat larger for the discrimination group than for the omission group, the absolute level of performance on forget-cue probe trials was about the same for the two groups. Instead, in the omission group the failure of 2 pigeons to maintain a high level of performance on remember trials can account for this difference. The data from the discrimination group appear in the top right panel of Figure 2.

In contrast to the omission and discrimination groups, pigeons in the substitution group

showed comparable levels of performance on remember-cue trials and forget-cue probe trials. Data from the substitution group appear in the bottom left panel of Figure 2.

Although only 1 pigeon in the reinforcement group (R1) was tested on forget-cue probe trials, the data from that pigeon were indistinguishable from those of the substitution group. Data from the pigeon in the reinforcement group appear in the bottom right panel of Figure 2.

A three-way mixed ANOVA was performed on the test data, with forget-cue reinforcement (whether reinforcement could follow the forget cue in training or not; the substitution and reinforcement groups vs. the omission and discrimination groups) and forget-cue discrimination (whether a discrimi-

nation followed the forget cue in training or not; the substitution and discrimination groups vs. the omission and reinforcement groups) as between-group factors and test trial type (performance on remember-cue trials vs. forget-cue probe trials in the test) as the repeated measure. The analysis indicated that there was a significant main effect of forget-cue reinforcement, $F(1, 9) = 35.12$. For groups for which forget cues were followed by reinforcement during training (the reinforcement and substitution groups), overall performance on test trials was more accurate than for groups for which forget cues were followed by the absence of reinforcement (the discrimination and omission groups). There was also a significant effect of trial type, $F(1, 9) = 7.93$. Performance on remember-cue trials was significantly more accurate, overall, than performance on forget-cue probe trials. Finally, there was a significant Reinforcement \times Trial Type interaction, $F(1, 9) = 6.21$. The disruption in performance on forget-cue probe trials was present only in groups for which food reinforcement did not follow the forget cue in training. In contrast, neither the effect of discrimination nor the Discrimination \times Trial Type interaction was significant, both $F_s < 1$.

A set of planned comparisons, performed on the forget-cue data alone, indicated that there was a significant main effect of reinforcement, $F(1, 9) = 50.93$; however, neither the effect of discrimination nor the Reinforcement \times Discrimination interaction was significant, both $F_s < 1$. Thus, the source of the Reinforcement \times Trial Type interaction in the three-way analysis can be attributed to more accurate matching on forget-cue probe trials by pigeons for which reinforcement followed forget cues in training.

Examination of cue pecking during probe-trial testing indicated that pigeons for which the forget cue was never followed by reinforcement (the omission and discrimination groups) pecked the forget cue (mean pecks per trial = 1.88) significantly less often than the remember cue (mean pecks per trial = 7.89), $F(1, 6) = 24.26$. On the other hand, pigeons for which the forget cue was almost always followed by reinforcement (the substitution and reinforcement groups) pecked the forget cue significantly more often (mean pecks per trial = 6.55) than the remember cue (mean pecks per trial = 3.41), $F(1, 3) = 10.64$. Thus, it appears that

delay-cue pecking is correlated with the relative rate of reinforcement associated with each cue. For pigeons in the substitution and reinforcement groups, the probability of reinforcement following forget cues was virtually 100%, whereas the probability of reinforcement following a remember cue was only 82.1%.

Unexpectedly, for each group, pecks to the remember cue (associated with a probability of reinforcement that was comparable for the four groups) appeared to vary inversely with the probability of reinforcement associated with the forget cue. Pigeons for which reinforcement followed the forget cue averaged 3.40 pecks per trial on remember-cue trials, whereas those for which reinforcement did not follow the forget cue averaged 7.89 pecks per trial. A one-way ANOVA performed on pecks to the remember cue indicated that there was a significant effect of reinforcement following the forget cue on remember-cue pecking, $F(1, 11) = 5.66$.

DISCUSSION

The results of this experiment indicate that the absence of reinforcement following the forget cue in training is sufficient to account for the decrement in performance observed on forget-cue probe trials (relative to remember trials). A decrement in performance on forget-cue probe trials was observed in both of the groups that in training received no food reinforcement on forget-cue trials; however, no such decrement was observed in the group that had received reinforcement but had not been required to make a discrimination following forget cues in training. Thus, contrary to Kendrick and Rilling's (1986) retrieval hypothesis, the presence of a discrimination following the forget cue in training is insufficient to maintain high levels of forget-cue probe-trial performance.

The present results confirm and extend the findings from earlier work that indicate the absence of disruption of matching accuracy when forget-cue training involves reinforced comparison responding (Kendrick et al., 1981; Maki & Hegvik, 1980; Maki et al., 1981). However, in other experiments, decrements in probe-trial performance have been found when substitution procedures involving reinforcement but no discrimination have been used

(Grant, 1981, Experiment 1; Grant & Barnet, 1991, nondifferential group¹). A successive-matching task was used in these latter studies, however, and Grant and Barnet (1991) explain that in the case of successive matching, the relative difficulty of the task ensures that the extended training required allows for better discriminability between the remember and forget cues. They suggest that the failure to find disrupted matching accuracy on forget-cue probe trials with a choice DMTS procedure results from the pigeons' failure to discriminate between remember and forget cues. According to this account, when reinforcement follows both remember and forget cues, it is difficult for the pigeon to discriminate between them. In the present research, although it is clear that the forget cue did not become an effective cue to forget, the notion that the pigeons were not able to discriminate the two cues can be rejected. Recall that pigeons in the two reinforcement groups (although there were only 5 of them) pecked the forget cue almost twice as often as they pecked the remember cue.

An alternative interpretation of the apparent forgetting found with substitution procedures that involve successive matching is that pigeons learn to withhold responding to a single comparison on trials without reinforcement (i.e., S- trials). As Roper and Zentall (1993) have argued, when such tasks are used, there is a strong incompatibility between the post-forget-cue response pattern acquired in training (nondifferential responding to any stimulus presented) and the post-forget-cue differential responding required on probe trials in the test. Furthermore, the successive-matching procedure appears to be particularly susceptible to novelty effects (i.e., the novel combination of a forget cue followed by a memory test). This susceptibility probably results from an asymmetry in the successive-matching task that is absent in choice DMTS. In successive matching, food is provided for correct comparison responding (pecking) on reinforcement (S+) trials, whereas no food is provided for correct comparison responding (not pecking) on S- trials. Thus, the penalty for not pecking on

S+ trials is the absence of food, whereas the penalty for pecking on S- trials is merely nonreinforced effort. Therefore, if there is any ambiguity resulting from the novelty of a forget cue followed by a comparison test, it should result in increased responding on S- trials. In choice DMTS, on the other hand, there should be no bias to respond to either comparison, so ambiguity due to probe-trial novelty should not result in a response bias. Thus, in the absence of independent supporting data, the claim that in the case of choice DMTS (but not successive matching), reinforcement prevents the development of an effective cue to forget (Grant & Barnet, 1991; Maki, 1981) would seem at best to be unparsimonious.

An alternative account of the absence of forget-cue probe-trial performance decrement has been proposed by Maki (1981). According to Maki, reinforcement that follows forget cues in training may adventitiously reinforce the maintenance of rehearsal. Thus, although memory for the sample is unnecessary on forget-cue trials in training, rehearsal is maintained if reinforcement follows that cue.

Maki (1981) came to this conclusion based on his finding that although presentation of a forget cue that signals the absence of reinforcement leads to the disruption of performance on forget-cue probe trials, presentation of an S- (trained off baseline) has little effect on matching accuracy (see also Roper, 1991). Thus, according to Maki, the role of the forget cue is not to signal the absence of reinforcement but rather is to signal the absence of the test, and the role of reinforcement is to adventitiously reinforce rehearsal of the sample. If a pigeon happens to rehearse during the delay on a forget-cue trial, that behavior will be adventitiously reinforced.

Alternatively, substitution procedures yield high levels of forget-cue probe-trial matching accuracy because remember and forget cues have similar motivational value and are associated with similar postcue response patterns. But what about the failure of an S- (trained off baseline) to function as a forget cue? Perhaps the difference is that the pigeons have had extensive experience with the forget cue in the context of DMTS, whereas there is a large generalization decrement in the inhibitory properties of the S- when introduced into the delay between sample and comparison stimuli.

¹ See also Kendrick, D. F., & Newman, D. R. (1984). *Procedural factors influencing directed forgetting in pigeon short-term memory*. Unpublished manuscript.

A surprising finding in the present experiment was the fact that 3 of the 4 pigeons in the reinforcement group were unable to recover performance on delayed-matching (i.e., remember-cue) trials. Although all pigeons showed some level of performance disruption, perhaps due to stimulus novelty when the remember cue was introduced (see Zentall, 1973), the fact that these 3 pigeons failed to recover performance in 150 sessions of training suggests that the procedure used with the reinforcement group may have been responsible for the failure to recover delayed-matching performance.

One distinguishing aspect of the procedure for the reinforcement group was that only one side key was presented following the forget cue and responses to it were always reinforced. Thus, on forget-cue trials, pecks by pigeons in this group were reinforced quickly and indiscriminately at the first side-key stimulus that appeared following the forget cue. To the extent that such rapid, indiscriminate, post-forget-cue pecking generalized to remember-cue trials, correct matching would likely be impaired. For the other three groups, however, rapid, indiscriminate, post-forget-cue pecking was not reinforced. For the substitution group, such key pecking following forget cues in training would have resulted in fewer reinforcements. For the discrimination group, rapid key pecks following forget cues in training would have resulted in additional required pecks to the incorrect comparison. Finally, for the omission group, there was no opportunity for rapid post-forget-cue pecking because in training stimuli were not presented following the forget cue. The 1 pigeon in the reinforcement group that recovered accurate DMTS performance presumably did not impulsively peck the single comparison. Not only did DMTS performance return to a high level relatively quickly for this pigeon, but there was also no disruption of performance on forget-cue probe trials.

To test the hypothesis that the failure to recover high levels of delayed-matching performance on trials following the introduction of remember cues resulted from the generalization to remember-cue trials of rapid post-forget-cue pecking to the side-key stimulus, 2 new pigeons (with a prior history similar to that of the original pigeons) were exposed to a variation of the procedure used for the re-

inforcement group. In this variation, no post-forget-cue side-key pecking was required. For these 2 pigeons, termination of the forget cue was accompanied by noncontingent reinforcement.

Although both pigeons rapidly acquired the delayed-matching task with mixed delays, results indicated that 1 of the 2 pigeons took 64 sessions to recover delayed-matching performance after the introduction of delay cues, and the other pigeon did not recover the baseline performance within 150 sessions. Thus, these 2 pigeons were indistinguishable from the pigeons in the reinforcement group, and it appears that rapid, indiscriminate, post-forget-cue pecking is not necessary to prevent the recovery of delayed-matching performance. Instead, it appears that for the rapid recovery of delayed-matching performance during delay-cue training, pigeons must either not peck following the forget cue (the omission group), or they must learn that following the forget cue they must pause to choose between the two side keys (the discrimination and substitution groups).

It is curious that in other DMTS directed forgetting experiments that have used either a single comparison stimulus following forget cues in training (Maki et al., 1981) or simply have followed forget cues with reinforcement (Kendrick et al., 1981), there was no mention of a problem with recovery of matching performance following the introduction of delay cues. The absence of such a problem may be due to the fact that the pigeons in these earlier experiments had previously served in directed forgetting experiments with substitution conditions involving a simple simultaneous discrimination. Extensive earlier experience with substitution procedures requiring choice of comparison stimuli may have been sufficient to prevent the rapid choice of comparisons on forget-cue probe trials, in spite of the later change in procedure (single stimulus and reinforcement or reinforcement alone) following the forget cue.

The present results also have implications for Roper and Zentall's (1993) response-pattern hypothesis. According to Roper and Zentall, when substitution procedures are used, high levels of forget-cue probe-trial performance should be found to the extent that the pattern of behavior required following a forget cue in training is compatible with the pattern

of behavior following the forget cue on a probe trial. Thus, little evidence of directed forgetting should be found if, in the context of DMTS, forget cues during training are followed by a simple simultaneous discrimination between the two side keys. In the present experiment, however, pigeons in the discrimination group had to discriminate between the side keys following a forget cue in training, yet substantial disruption of performance was found on forget-cue probe trials. Thus, it appears that response-pattern compatibility may be necessary, but is not sufficient, to prevent the disruption of performance on forget-cue probe trials (see the discrimination group). Instead, if reinforcement is absent following a forget cue in training (the omission and discrimination groups), or if there is an incompatibility between the post-forget-cue response pattern in training and that on probe trials (see Roper & Zentall, 1993), there will be a decrement in performance on forget-cue probe trials.

With regard to the response-compatibility hypothesis, the prediction for pigeons in the reinforcement group is similar to that for pigeons in the substitution group. Although no discrimination was required of pigeons in the reinforcement group, the post-forget-cue response pattern acquired in training (peck the left or the right response key) should be compatible with the response pattern required on forget-cue probe trials and thus, a high level of performance should be found on forget-cue probe trials. Results from the pigeon in the reinforcement group that recovered its baseline level of performance on remember-cue trials indicate that the availability of reinforcement, together with the presumed response compatibility following forget cues, appear to have been sufficient to eliminate performance disruption on probe trials. This finding is consistent with results reported by Maki *et al.* (1981, Experiment 1).

On the other hand, according to the response-compatibility hypothesis, disrupted probe-trial performance should be found when, in training, no pecking is required following a forget cue (*i.e.*, when the two response patterns are incompatible). Of the 2 pigeons described earlier that were trained with a reinforcement procedure in which responding was not required after the forget cue, the one that recovered baseline performance was tested with

forget-cue probe trials. Consistent with the response-competition hypothesis, this pigeon performed at 79.7% correct on remember-cue trials but at only 57.0% correct on forget-cue probe trials.

Furthermore, this finding is inconsistent with Maki's (1981) contention that when reinforcement follows a forget cue, it adventitiously reinforces sample rehearsal. The tested pigeon also responded at a high rate to the forget cue (mean pecks per trial = 5.53) and at a lower rate to the remember cue (mean pecks per trial = 2.27). Thus, contrary to the hypothesis proposed by Kendrick *et al.* (1981), that delay-cue pecking is an indication of sample rehearsal and thus, matching accuracy, it appears that a high rate of forget-cue pecking is not necessarily associated with a high level of probe-trial performance. Although a high rate of forget-cue pecking was found for the substitution and reinforcement groups and not for the omission and discrimination groups, a high rate of forget-cue pecking was also found for the pigeon trained with reinforcement immediately following the forget cue. For this pigeon, performance on forget-cue probe trials was greatly disrupted. Apparently, as mentioned earlier, the rate of forget-cue pecking is a function of the probability of reinforcement following the delay, rather than a predictor of the level of performance on forget-cue probe trials (see also Roper & Zentall, 1994).

Overall, the results of the present experiment suggest that either the absence of reinforcement on forget-cue trials in training or an incompatibility between responding following forget cues in training and forget-cue probes in the test is sufficient to result in the disruption of performance on forget-cue probe trials. Thus, when these two-choice DMTS procedures are used in the study of directed forgetting in pigeons, it is not necessary to posit memory loss (or an active memory process that can be terminated when not required) to account for the disruption in performance on forget-cue probe trials. Instead, it is more parsimonious to account for these effects in terms of motivational or response-pattern artifacts.

Roper, Kaiser, and Zentall (*in press*) have recently proposed that true directed forgetting is not likely to occur with the kind of procedures used in much of the directed forgetting research with animals as well as those used in the present study. Instead, they have proposed

that true directed forgetting should occur only when the forget cue signals that it is profitable to *reallocate* memory (i.e., when forgetting the sample can increase the probability of reinforcement). Roper et al. trained pigeons with compatible responses and with reinforcement following forget cues. In this experiment it was demonstrated that performance on forget-cue probe trials could still be disrupted when the forget cue signaled that memory for a stimulus other than the sample (in this case memory for the forget cue itself) was required. Such a procedure is more analogous to directed forgetting procedures typically used with humans (in which presentation of a forget cue provides time during which items presented earlier and followed by a remember cue can be maintained in memory, e.g., Archer & Margolin, 1970; MacLeod, 1975) than the simple delayed-matching procedures typically used with animals.

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