Establishing a forget cue in pigeons using the intratrial interference procedure

DOUGLAS S. GRANT

University of Alberta, Edmonton, Alberta, Canada

Pigeons were trained in an intratrial interference preparation in which a horizontal or vertical line was presented for 1 sec immediately following termination of a sample (red or green). Two samples were presented successively on interference trials. Choice of the comparison corresponding to the second (target) sample was designated correct and was reinforced, and choice of the comparison corresponding to the first (interfering) sample was designated incorrect and was not reinforced. Control trials involved the presentation of a single, target sample. A horizontal line was presented upon termination of an interfering sample, and a vertical line was presented upon termination of a target sample. The results of three experiments led to the conclusion that the horizontal line acquired and capacity to reduce postperceptual processing (rehearsal) of information derived from an immediately preceding sample stimulus. These findings include (1) convergence of accuracy on control and interference trials as training progressed, (2) a reduction in accuracy on control and especially on interference trials when the correlation between sample type (interfering or target) and cue type (horizontal or vertical) was reduced to zero, (3) higher accuracy (i.e., less interference) when the horizontal rather than the vertical line followed the interfering sample, and (4) higher accuracy on single-sample trials when the vertical rather than the horizontal line followed sample presentation.

Several recent studies have demonstrated that short-term retention in pigeons (Grant, 1981b, 1984a; Kendrick, Rilling, & Stonebraker, 1981; Maki & Hegvik, 1980; Maki, Olson, & Rego, 1981; Stonebraker & Rilling, 1981; Stonebraker, Rilling, & Kendrick, 1981), monkeys (Roberts, Mazmanian, & Kraemer, 1984), and rats (Grant, 1982b) is influenced by presentation of cues to remember or to forget. Research using pigeons and monkeys has employed a delayed matching-to-sample procedure in which the sample presentation on each trial is followed by a postsample cue. In a typical experiment, termination of the sample (e.g., a red or green field) is followed by one of two postsample cues (e.g., vertical or horizontal line). Trials in which one of the postsample cues, say vertical, is presented terminate in the standard retention test. On the other hand, on trials in which the alternate postsample cue (horizontal in the present example) is presented, no test for sample memory occurs. Thus, the vertical line may be defined procedurally as a remember cue because it signals the relevance of sample memory to trial outcome (reinforcement or nonreinforcement). Similarly, the horizontal line may be defined procedurally as a forget cue because it signals the irrelevance of sample memory to trial outcome. After extensive exposure to this training regime, memory for the sample is tested occasionally on forget-cued probe trials. The basic finding is that matching accuracy is significantly lower on

forget-cued trials than on remember-cued trials, a phenomenon referred to as directed forgetting.

One question of interest concerns the conditions that are necessary and sufficient for a postsample cue to acquire the capacity to function as an effective cue to forget. In an earlier paper (Grant, 1981b), I suggested that a sufficient condition for establishing an effective forget cue is that the cue signal the irrelevance of the sample memory to test responding. That suggestion was based on the finding that a postsample cue will come to function as an effective forget cue if on such trials either the comparison stimuli are omitted or a stimulus requiring nondiscriminative responding is presented (e.g., Grant, 1981b, 1982b; Kendrick, cited in Rilling, Kendrick, & Stonebraker, 1984; Maki & Hegvik, 1980; Maki et al., 1981). However, subsequent studies have shown that requiring discriminative, albeit sample-independent, responding on forget-cued trials results in the postsample cue's failing to function as an effective cue to forget (Kendrick, cited in Rilling et al., 1984; Kendrick et al., 1981; Maki et al., 1981). Thus, it is clear that irrelevancy is not a sufficient condition to produce an effective cue to forget.

More recently, Rilling et al. (1984) have suggested that a postsample cue will become an effective cue to forget only if that cue is presented on trials that do not require attention to subsequent events and stimuli on that trial. In their words, "Directed forgetting is only obtained when the F-cue switches attention away from the matching procedure" (p. 187). Because of the emphasis upon processes of attention, this hypothesis will be referred to as the "attention hypothesis." The attention hypothesis accounts for the fact that comparison omission and comparison substitution of the nondiscriminative type result

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in an effective forget cue, whereas comparison substitution of the discriminative type does not. That is, the former procedures do not require attention to subsequent events and stimuli and therefore result in an effective forget cue, whereas the latter procedure does require attention to subsequent events and stimuli and therefore does not result in an effective cue.

The present experiments were designed to test the attention hypothesis of Rilling et al. (1984). This was accomplished by attempting to establish a postsample stimulus as a cue to forget, even though on such trials attention to subsequent events and stimuli was required. Specifically, an intratrial interference preparation was employed in which each sample presentation (red or green field) was followed by a postsample cue (horizontal or vertical line). One half of the trials were control trials in which a single sample stimulus was presented. Termination of the sample was followed by a 1-sec presentation of a vertical line. Comparison stimuli, one red and one green, were presented immediately following termination of the vertical line, and choice of the comparison that matched the sample was reinforced. The remaining half of the trials were interference trials in which both colors were presented sequentially as samples. The sample sequence was equally often red then green and green then red. Responding to the comparison that matched the second (target) sample was defined as correct and was reinforced; responding to the comparison that matched the first (interfering) sample was defined as incorrect and was not reinforced. The interfering sample was always followed by a 1-sec presentation of a horizontal line, and the target sample was always followed by a 1-sec presentation of a vertical line. Thus, the target sample on both types of trials was always followed by a vertical line and the interfering sample on interference trials was followed by a horizontal line. Because of this cuing arrangement, responding on the basis of a sample followed by a vertical line led to a correct (reinforced) test response. On the other hand, responding on the basis of a sample followed by a horizontal line led to an incorrect (nonreinforced) test response. The question of interest was whether the horizontal line would come to function as an effective cue to forget.

Consider first the prediction derived from the attention hypothesis. Because the horizontal line was always followed by presentation of the target sample and comparison stimuli, the horizontal line could not switch attention away from the matching procedure. It would therefore be anticipated that the horizontal line would not function as an effective cue to forget. On the other hand, conceptions of directed forgetting emphasizing control of post-perceptual processing or rehearsal (Grant, 1981a, 1984b; Maki, 1981) might anticipate that the horizontal line would become a particularly robust cue to forget. Notice that in the standard training of an effective forget cue, the cue signals merely that memory for the sample is not required. Thus, whether the bird does or does not rehearse the sample memory on such trials is irrelevant, and the bird comes to reduce processing when it encounters a forget cue

presumably because such processing is effortful. In the present training regime, however, the horizontal line signals not the irrelevancy of the prior sample, but that responding on the basis of the prior sample will result in nonreinforcement. In the present training regime, then, the probability of reinforcement at testing is actually increased by terminating rehearsal of the preceding sample memory when a horizontal line is encountered.

EXPERIMENT 1

Birds were trained to match using red and green fields as sample and comparison stimuli. In the next phase (correlated cues training), postsample cues were introduced and sessions were composed of an equal number of control and interference trials. Control trials were standard matching trials, except that a vertical line was presented for 1 sec immediately following sample termination. Interference trials involved the sequential presentation of both colors as sample stimuli; the sample sequence was equally often red then green and green then red. Responding to the comparison that matched the second (target) sample was defined as correct and was reinforced; responding to the comparison that matched the first (interfering) sample was defined as incorrect and was not reinforced. The interfering sample was always followed by a horizontal line, and the target sample was always followed by a vertical line. Thus, the target sample on both types of trials was always followed by a vertical line and the interfering sample on interference trials was always followed by a horizontal line. Following 84 sessions of training with cues and sample type perfectly correlated, a second phase was introduced. This phase was identical to correlated cues training except that each of the lines was equally likely to follow each type of sample. In this phase, called uncorrelated cues training, the postsample cues provided no information concerning whether the preceding sample was an interfering or target sample. Following 84 sessions of training with uncorrelated cues, an additional 28 sessions of training with correlated cues was administered.

It is well known that pigeons match more accurately on control trials than on intratrial interference trials in the absence of postsample cues (Grant, 1982a; Grant & Roberts, 1973; Zentall & Hogan, 1974, 1977). Moreover, the interference effect persists across sustained testing. For example, Grant and Roberts (1973) tested birds for 68 sessions (32 in Experiment 1 and 36 in Experiment 2), involving control and interference trials, with no significant reduction in the magnitude of the interference effect. In the present preparation, however, the birds could use the horizontal line as a signal to reduce processing of the memory derived from the preceding sample. If this were so, then the magnitude of the interference effect should be reduced as training with correlated cues progressed. In other words, accuracy on control and interference trials should converge. This is the case because failure to rehearse the memory activated by the interfering sample

should result in rapid forgetting, and hence a decreased probability that the interfering memory will control test responding.

If the horizontal line functions as a cue to forget at the end of correlated cues training, then accuracy on both control and interference trials should drop when uncorrelated cues training is introduced. Moreover, accuracy on interference trials should decline more than that on control trials. Accuracy should decline on control trials because the sample on half of these trials is followed by the horizontal line. Accuracy on interference trials should decline particularly markedly because (1) the birds no longer have a postsample cue that reliably indicates that the preceding sample was the interfering sample, and (2) the target sample is followed by a cue to forget on half of the trials. As training continues, the birds should learn that the cues now have no significance and accuracy on control and interference trials should increase. Although accuracy on control trials should reach the level attained at the end of training with correlated cues, accuracy should be less on interference trials than at the end of training with correlated cues. This is the case because interference cannot be mitigated by a directed forgetting effect. Finally, returning the birds to training with correlated cues should result in a gradual convergence of accuracy on control and interference trials as the birds relearn that the horizontal line is a cue to forget.

Method

Subjects

Six naive Silver King pigeons were reduced to and maintained at 80% of their free-feeding weights.

Apparatus

The birds were tested in six identical chambers. Three pecking keys were mounted horizontally in a row 20 cm above the floor in each chamber. An Industrial Electronics, Inc., in-line projector was mounted behind each key and was used to project stimuli onto the pecking key. A 28-V houselight was mounted directly above the center pecking key. The housing was adjusted such that the light emitted by the houselight was directed toward the ceiling. The houselight remained illuminated throughout each session except for a 3-sec period following incorrect comparison responses. A grain feeder was mounted below the center pecking key. Each test chamber was enclosed in a sound- and light-attenuating enclosure. Masking noise was provided by an exhaust fan within the enclosure and by white noise delivered through a speaker in the testing room. The presentation of events within the chambers and the recording of data were accomplished using microcomputers.

Procedure

Preliminary training. The birds were trained to eat grain from the magazine and were then autoshaped to peck red and green fields presented on the side keys. After each bird was responding reliably, training on simultaneous matching-to-sample began. Trials were separated by an intertrial interval of 20 sec and began with presentation of a black dot on a white background as a preparatory stimulus. The preparatory stimulus was presented on the center key and remained illuminated until a single response occurred or, in the absence of a response, for 5 sec. Termination of the preparatory stimulus was followed immediately by presentation of either a red or green sample stimulus on the center key. After 5 sec had

elapsed, the side keys were illuminated, one red and the other green. The sample remained illuminated until the bird pecked one of the comparison stimuli. A single response to the matching comparison produced 3-sec access to grain and was followed by the intertrial interval. A single response to the nonmatching comparison produced a 3-sec blackout which was followed by a second presentation of the sample and comparison stimuli. Correction opportunities continued until the bird responded to the matching comparison stimulus. Sessions consisted of 96 trials, and each color served as the sample on 48 trials. The correct comparison was equally often on the right and left key within each sample color. After 16 sessions, the birds were matching accurately (mean percentage correct = 95.0) and 12 additional sessions were run with the only change being the elimination of the correction procedure. Finally, an additional 12 sessions were run with the only change being that the sample was terminated immediately prior to onset of the comparison stimuli. Training on 0-sec delayed matching-to-sample continued for 12 sessions. Mean accuracy during the final 4 sessions of training was 97.3% correct.

Training with correlated cues: 1. Sessions consisted of 96 trials, 48 control trials and 48 intratrial interference trials. Control trials were identical to the 0-sec delayed matching trials except that a vertical line was presented for 1 sec immediately following termination of the sample. Presentation of red and green comparison stimuli followed immediately after termination of the line. On interference trials, both red and green were presented as samples, each for 5 sec. The sequence was equally often red then green and green then red. The first (interfering) sample was followed by a 1-sec presentation of a horizontal line, and the second (target) sample was followed by a 1-sec presentation of a vertical line. Red and green comparison stimuli were presented immediately following termination of the vertical line. A response to the comparison which matched the second, target sample was defined as correct and produced a reinforcer. A single response to the comparison which matched the first, interfering sample was defined as incorrect and produced a blackout. Position of the correct comparison stimulus was equally often right and left on each of the four types of trials (control red sample, control green sample, interference red then green sample, and interference green then red sample). Trials were separated by an intertrial interval of 30 sec. The order in which the various trial types were tested was determined randomly each session. Training continued for 84 sessions. All other aspects of the procedure were the same as those in 0-sec delayed matching training.

Training with uncorrelated cues. The sessions were identical to those during correlated cues training except for the following modifications. Rather than always being followed by the vertical line, the sample on control trials was equally often followed by the vertical or horizontal line. On half of the interference trials, the interfering sample was followed by the horizontal line and the target sample was followed by the vertical line. On the remaining interference trials, the cuing sequence was the reverse, interfering sample followed by the vertical line and target sample followed by the horizontal line. Training continued for 84 sessions.

Training with correlated cues: 2. The sessions were identical to those during training with correlated cues: 1. Training continued for 28 sessions.

Results and Discussion

Mean percentage of correct responses on control and interference trials as a function of blocks of four sessions in each of the three phases is shown in Figure 1. During training with correlated cues, matching accuracy was higher on control trials than on interference trials [$F(1,5) = 29.46, p < .01$], particularly during the initial blocks of training. Accuracy on both types of trials increased

Figure 1. Mean percentage of correct responses on interference and control trials in each of the three phases in Experiment 1.

across blocks [$F(20,100) = 12.37, p < .001$], particularly on interference trials [blocks $\times$ trial type interaction, $F(20,100) = 2.60, p < .001$]. Accuracy on interference trials was 20.1 percentage points less than that on control trials during the first block of training with correlated cues, and was only 3.5 percentage points less during the final block. These findings are consistent with the hypothesis that the horizontal line, which always followed an interfering sample and never followed a target sample during this phase, functioned as a forget cue to reduce or terminate processing of the interfering sample memory.

If the horizontal line functioned as a forget cue at the end of Phase 1, then randomizing the relationship between sample type (interfering or target) and cue type (horizontal or vertical) should reduce accuracy on both control and interference trials. Moreover, accuracy on interference trials should be disrupted more markedly. Examination of the data from the first block of training with uncorrelated cues reveals that both of these predictions were confirmed. Comparing accuracy on the first block with uncorrelated cues to that on the last block with correlated cues shows that accuracy was 17.2 percentage points lower on control trials and was 29.0 percentage points lower on interference trials. An analysis of variance (ANOVA) performed on data from the last block with correlated cues and the first block with uncorrelated cues revealed significant effects of phase (correlated vs. uncorrelated cues) [$F(1,5) = 153.50, p < .001$] and trial type [$F(1,5) = 15.70, p < .05$]. The phase $\times$ trial type interaction fell just short of significance [$F(1,5) = 6.48, p = .0515$].

Across blocks of training with uncorrelated cues, accuracy was higher on control trials than on interference trials [$F(1,5) = 7.32, p < .05$] and improved across blocks [$F(20,100) = 8.30, p < .001$]. Unexpected was the finding that accuracy on control and interference trials converged, and at the end of this phase was only 2.1 percentage points higher on control trials than on interference trials. The convergence of accuracy on the two types of trials resulted in a significant blocks $\times$ trial type interaction [$F(20,100) = 3.40, p < .01$]. Although specification of the mechanism responsible for this latter finding will require additional research, it may be that prolonged exposure to control and interference trials results in birds' learning to stop processing a sample memory if a second sample is presented on a trial. In other words, onset of a second sample on a trial may function as an implicit forget cue to reduce or halt processing of the memory derived from presentation of the interfering sample. Interestingly, Grant and Roberts (1973) found no such convergence in birds receiving no postsample cues of any kind. It may be that exposure to correlated cues training is a necessary prerequisite for presentation of a second sample to reduce processing of memory derived from a preceding sample.

The birds were returned to training with correlated cues during the final phase. An ANOVA comparing performance during the final block of uncorrelated cues training with the first block of training with correlated cues revealed nonsignificant effects of phase [$F(1,5) = 3.81, p > .05$] and trial type ($F < 1$). The interaction was also nonsignificant ($F < 1$). A blocks $\times$ trial type ANOVA

performed on the seven blocks of training with correlated cues failed to reveal any significant terms.

The results of the present experiment support the notion that a cue that reliably follows the interfering sample in an intratrial interference preparation will function as a cue to forget. Consistent with this view are the findings that (1) accuracy on control and interference trials converged as training with correlated cues progressed, and (2) accuracy on both types of trials, and particularly on interference trials, was disrupted when the cues were presented in a random relationship to sample type. The results of continued training with uncorrelated cues suggest caution in accepting this conclusion. In particular, the fact that accuracy on control and interference trials converged across blocks in Phase 2, even though the cues had no information value, suggests that a similar convergence observed in Phase 1 may have occurred independently of the cuing procedure. That is, the birds may have learned to stop processing a memory when a second sample was presented on a trial, and not when a horizontal line was presented. Notice, however, that the disruption of accuracy that occurred when the birds were transferred to training with uncorrelated cues suggests that the cues did acquire control. That is, if the birds were not using the cues at the end of Phase 1, then performance should not have been disrupted by randomizing the relationship between sample type and postsample cue. Particularly problematic for this view is the finding that accuracy was more markedly disrupted on interference trials than on control trials. The latter finding supports the view that during training with correlated cues the horizontal line did acquire the capacity to function as a cue to forget. The second and third experiments were designed to test this notion further.

EXPERIMENT 2

Grant (1984a) established effective forget and remember cues on single sample trials and then tested their effectiveness on double-sample interference trials (for conceptually similar experiments using rats, see Grant, 1982b). In one type of test, birds were exposed to two types of intratrial interference trials. On R-R trials, a 1-sec remember cue immediately followed the interfering sample and the target sample. On F-R trials, a 1-sec forget cue followed the interfering sample and a 1-sec remember cue followed the target sample. The argument was that, to the extent that a forget cue reduces processing of information derived from an immediately preceding sample stimulus, accuracy should be higher on F-R trials than on R-R trials. That is, interference should be reduced on F-R trials because the bird should stop processing the interfering memory and hence that memory should be forgotten more rapidly than it would be forgotten on R-R trials. In accord with this hypothesis, it was found that accuracy was 10.3 percentage points higher on F-R trials than on R-R trials.

The present experiment also involved comparing accuracy on F-R and R-R interference trials. On F-R trials,

the horizontal line, which always followed an interfering sample during correlated cues training, was presented following the interfering sample and the vertical line, which always followed a target sample during correlated cues training, was presented following the target sample. On R-R trials, the vertical line was presented following both the interfering and target samples. The question of interest was whether, as in Grant's (1984a) experiments, accuracy on F-R trials would exceed that on R-R trials. If the horizontal line functioned as a cue to forget, one would anticipate such an effect.

Although the technique used to assess the effectiveness of a forget cue in the present experiment is identical to that employed by Grant (1984a, Experiment 1), the two experiments differ with respect to the training conditions employed to establish the forget cue. In my earlier experiment, the forget cue was established by training on single sample trials in which the memory test was omitted on trials containing the forget cue. In the present case, the forget cue (horizontal line) was established by training on double-sample interference trials in which the forget cue followed the interfering sample (i.e., correlated cues training of Experiment 1). If the present training regime does result in the establishment of an effective cue to forget, then accuracy should be higher on F-R trials than on R-R.

Method

Subjects and Apparatus

The subjects and apparatus were the same as those used in Experiment 1.

Procedure

The procedure involved three identical test phases, each separated by 24 sessions of training. Test 1 began on the session following completion of Experiment 1. Four sessions of testing alternated with 4 sessions of baseline training. Baseline training sessions were identical to correlated cues training sessions in Experiment 1. That is, a vertical line followed the target sample on both control and interference trials and a horizontal line followed the interfering sample on interference trials (48 control and 48 interference trials per session). Test sessions were identical to baseline training sessions, except that 16 of the 48 interference trials were probes. Eight of the 16 probes were R-R probes. These trials were identical to baseline interference trials, except that a 1-sec vertical line, rather than a horizontal line, followed the interfering sample. The remaining 8 probe trials were F-R probes which were identical to those of baseline interference trials.

Following the final session of Test 1, the birds were returned to baseline training (called "correlated cues training" in Experiment 1) for 24 sessions. Test 2, which was identical to Test 1 in all aspects, began on the session following completion of training. An additional 24 sessions of baseline training followed Test 2. Test 3, which was identical to Tests 1 and 2 in all aspects, began on the session following training.

Results and Discussion

Mean percentage of correct responses as a function of trial type in each of the three tests is shown in Figure 2. Performance on F-R baseline trials (32 observations per test session) and F-R probe trials (8 observations per test session) was equivalent in each of the three tests. This

finding reveals that accuracy on probe trials is reliable. Also notice that accuracy on control (R) and F-R interference trials was approximately equivalent in each of the three tests. That is, presenting an interfering sample prior to the target sample did not produce interference when the interfering sample was followed by the horizontal line (F-R trials).

The comparison of primary interest involved accuracy on F-R and R-R probe trials. In Test 1, no difference on the two types of probe trials was obtained. It is possible that the 28 sessions of correlated cues training that followed the 84 sessions of uncorrelated cues training in Experiment 1 was insufficient to permit the horizontal line to reacquire a forget cue function. Therefore, an additional 24 sessions of training with correlated cues followed Test 1. Test 2, which was an exact replication of Test 1, followed the final session of training. In this test, accuracy was 7.8 percentage points higher on F-R probes than on R-R probes. Five of the six birds matched more accurately on F-R probes than on R-R probes; the remaining bird showed no difference. To assess the reliability of this finding, a third test was conducted following 24 additional sessions of correlated cues training. Test 3 again revealed higher accuracy on F-R than on R-R probes (difference = 8.8 percentage points), and this effect was shown by all six birds. Statistical analysis revealed that accuracy was significantly higher on F-R probes than on R-R probes in both Test 2 [$F(1,5) = 7.96, p < .05$] and Test 3 [$F(1,5) = 10.47, p < .05$].

The findings of Tests 2 and 3 support the notion that a cue that reliably follows the interfering sample in an intratrial interference preparation acquires a capacity to terminate or reduce processing of information derived from an immediately preceding sample stimulus. The final experiment tested this notion using an alternative assessment technique.

Figure 2. Mean percentage of correct responses as a function of trial type in each of three tests in Experiment 2.

EXPERIMENT 3

The results of the first two experiments have been interpreted as supporting the notion that the horizontal line acquired the capacity to reduce processing of information derived from a preceding sample presentation. It is possible, however, that the horizontal line acted proactively and influenced the processing of the target sample. Specifically, the horizontal line may have been a signal to pay particular attention to the next event presented (i.e., the target sample). If so, better accuracy on F-R trials than on R-R trials would be anticipated, not because the birds forgot the interfering sample more rapidly on F-R trials than on R-R trials, but because they attended more strongly to the target sample on F-R trials than on R-R trials.

The present experiment assessed this alternative account by employing the more traditional single-sample assessment technique to determine whether the horizontal line functioned as an effective cue to forget. That is, accuracy on two types of single-sample (control) trials was compared: On R trials, the single sample was followed by the vertical line, and on F trials, the single sample was followed by the horizontal line. To the extent that the horizontal line functioned as a cue to forget, accuracy should be higher on R trials than on F trials. On the other hand, if the horizontal line functions only to enhance attention to subsequent sample stimuli, then accuracy on the two types of trials should be equivalent.

Method

Subjects and Apparatus

The subjects and apparatus were the same as those used in Experiments 1 and 2.

Procedure

The procedure involved two identical test phases, each separated by 4 sessions of training. On the session following the completion of Experiment 2, training began on 16 baseline training sessions which were identical to the correlated cues training sessions in Experiment 1. That is, a vertical line followed the target sample on both control and interference trials and a horizontal line followed the interfering sample on interference trials (48 control and 48 interference trials per session). Test 1 began on the session following training and involved 3 test sessions which alternated with 3 baseline sessions. Test sessions were identical to baseline training sessions except that 16 of the 48 control trials were probes. Eight of the 16 probes were R probes, which were identical to standard control trials (a 1-sec vertical line followed the target sample). The remaining 8 probe trials were F probes, which were identical to R probes except that a 1-sec horizontal line followed the sample. Four sessions of baseline training intervened between Test 1 and Test 2. Test 2 was identical to Test 1 in all aspects.

Results and Discussion

Mean percentage of correct responses as a function of trial type in each test is shown in Figure 3. Performance on R baseline trials (32 observations per test session) and

Figure 3. Mean percentage of correct responses as a function of trial type in each of the two tests in Experiment 3.

R probe trials (8 observations per test session) was equivalent in each test. This finding reveals that accuracy on probe trials is reliable. Also notice that accuracy on R control and F-R interference trials was approximately equivalent in each test. As in the preceding experiments, presenting an interfering sample prior to the target sample did not produce interference when the interfering sample was followed by the horizontal line.

The comparison of primary interest concerned accuracy on R-probe and F-probe control trials. In both tests, accuracy was higher on R-probe trials than on F-probe trials (26.3 percentage points in Test 1 and 21.5 percentage points in Test 2). All six birds matched more accurately on R probes than on F probes in both tests. Statistical analysis revealed that matching was more accurate on R probes than on F probes in both Test 1 [$F(1,5) = 26.65, p < .01$] and Test 2 [$F(1,5) = 22.95, p < .01$]. These results are exactly as anticipated on the basis of the notion that the horizontal line functioned as a forget cue to reduce processing of information derived from an immediately preceding sample. Moreover, the notion that the horizontal line functions only to enhance attention to subsequently presented sample stimuli cannot account for the findings of the present experiment.

GENERAL DISCUSSION

The present experiments were designed to determine whether a postsample cue (horizontal line) which reliably followed the interfering sample in an intratrial interference preparation would come to function as a forget cue to reduce processing (or rehearsal) of information derived from a preceding sample. A number of the present findings permit an affirmative answer. In Experiment 1, it was found that accuracy converged on control and interference trials across blocks of training with correlated cues, and that accuracy was lowered, particularly on interference trials, when the correlation between postsample cue and sample type (interfering or target) was reduced

to zero. The fact that accuracy on control and interference trials tended to converge also during training with uncorrelated cues suggests caution in attributing the convergence observed during training with correlated cues to a forget cue function associated with the horizontal line. Nonetheless, the pattern of disruption observed when birds were shifted from training with correlated cues to training with uncorrelated cues supports the notion that presentation of the horizontal line reduced rehearsal of information derived from the preceding sample.

The second and third experiments provided additional, and perhaps more powerful, support for the notion that a postsample cue that reliably follows the interfering sample will function as a cue to forget. In Experiment 2, accuracy was higher (i.e., interference was less) when the horizontal line followed the interfering sample (F-R probes) than when a vertical line followed the interfering sample (R-R probes). Experiment 3 revealed that accuracy on single-sample control trials was higher when the vertical line followed sample presentation (R probe) than when the horizontal line followed sample presentation (F probe).

It is interesting to note that both Experiment 2 and Experiment 3 obtained evidence that the horizontal line functioned as a forget cue in spite of the fact that the data from uncorrelated cues training in Experiment 1 suggested that the cues were not required to maintain high accuracy on interference trials. That is, at the end of training with uncorrelated cues, the magnitude of the interference effect was no greater than at the end of the first phase of training with correlated cues. As noted earlier, this finding suggests that the birds were able to discriminate the interfering and target sample on some basis other than the type of cue which followed the sample. The most obvious basis for such a discrimination is the occurrence of a second sample; onset of a second sample could function as a cue to reduce processing of information derived from a preceding sample. The question then arises as to why, when the birds were returned to training with correlated cues, the horizontal line reacquired the capacity to function as a cue to forget. Perhaps the simplest answer is that the horizontal line occurred sooner after termination of the interfering sample than did onset of the second sample. Thus, although two events may have signaled that the preceding sample was not to be remembered, the horizontal line was more informative because it preceded onset of the second sample.

Although the interpretation of the present data favored here is that the horizontal line functioned to reduce processing of information derived from an immediately preceding sample stimulus, an alternative account emphasizing memory for serial compounds deserves some consideration. According to this view, the birds learned to respond on the basis of the specific sequence of events which preceded the test. This view suggests that during training with correlated cues, the birds learned a set of four "if-then rules." The "choose green" instruction would be activated by the two-element sequence green

followed by vertical and by the four-element sequence red followed by horizontal followed by green followed by vertical. The "choose red" instruction would be activated by the two-element sequence red followed by vertical and by the four-element sequence green followed by horizontal followed by red followed by vertical.

Several aspects of the present data may be accounted for by the serial compound view on the reasonable assumption that accuracy will be reduced on trials on which the sequence of events differs from those employed during training. Thus, for example, accuracy should be lower on two-element sequences in which a color is followed by horizontal (called F-cued trials here) than on trials in which a color is followed by vertical (called R-cued trials here) because the sequence on the former trial types differs from the sequence employed during training. As a second example, accuracy should be lower on four-element sequences in which vertical follows the presentation of each color (called R-R trials here) than on trials in which horizontal follows the first color in the sequence and vertical follows the second color in the sequence (called F-R trials here).

Although the serial-compound interpretation cannot be refuted definitively on the basis of the available data, at least two considerations suggest that it is a less viable account than the directed-forgetting account. First, the serial-compound view requires that the birds learned to respond on interference trials on the basis of four-element sequences. In order to perform in this fashion, the birds would have to remember each of four events (two colors and two line orientations) and their temporal order on interference trials. From an information processing perspective, such a strategy would seem to require more complex processes than would be required on the view that presentation of the horizontal line reduced processing of information derived from the immediately preceding color sample. Thus, parsimony would favor the directed-forgetting account. Second, following completion of the third experiment, the birds were returned to standard matching employing color samples that were not followed by cues of any kind. The serial-compound view would anticipate markedly reduced accuracy on such single-element trials relative to accuracy on two-element sequences of the form red followed by vertical and green followed by vertical. In fact, it may be argued that removing the cues entirely should represent a larger change from the conditions of training than should replacing the vertical line by a horizontal line. If so, accuracy should be lower on no-cue trials than on the trials referred to as F-cued trials in Experiment 3 of the present series. Contrary to this prediction, the birds matched with a high degree of accuracy on the very first session employing no-cue trials (94.6% at a 0-sec delay and 79.6% at a 2-sec delay). Thus, the serial-compound view does not represent a strong competitor to the view that the horizontal line functioned as a forget cue and reduced process-

ing of information derived from the immediately preceding sample stimulus.

The finding that the horizontal line functioned as a cue to forget is inconsistent with the attention hypothesis of Rilling and his associates (Kendrick & Rilling, 1986; Rilling, Kendrick, & Stonebraker, 1984). Recall that, according to that view, a postsample stimulus will acquire the capacity to function as a forget cue only if it switches attention away from the matching task. The attention hypothesis encounters difficulty in the present case because attention to subsequent events (the target sample and comparison stimuli) and discriminative responding (at the time of comparison presentation) was required on trials in which the horizontal line was presented. Nonetheless, the horizontal line functioned as an effective cue to forget.

It may be noted that, in an article appearing after initiation of the present research, Colwill (1984) reported data which may be viewed as inconsistent with the attention hypothesis of Rilling et al. Birds were trained with samples of food and no food. The comparisons were equally likely to consist of two colors (red and green) or two line orientations (horizontal and vertical). One member of each comparison pair was correct given a food sample, and the alternate member was correct given a no-food sample. Following acquisition of matching, a clicker was presented during the retention interval on some trials involving a food sample and color comparisons. On these trials a response appropriate to a no-food sample was reinforced. After extensive training, presentation of the clicker led to choice of the color associated with the no-food sample on about 75% of the trials, suggesting that the clicker functioned as a cue to forget the food sample. Moreover, the clicker was equally effective when tested on transfer trials involving a food sample and line comparisons. Even though the clicker had not been presented on line-comparison trials during training, the birds responded to the line comparison appropriate to a no-food sample on about 75% of the transfer trials.

Although Colwill (1984) discusses a number of alternative interpretations of her findings, her data and those reported here are consistent with the notion that a postsample stimulus that signals that responding on the basis of a prior sample will lead to nonreinforcement acquires the capacity to function as a cue to forget. Moreover, such a stimulus will function as a cue to forget even though that stimulus does not direct attention away from the matching task. It is thus clear that switching attention away from the matching task is not a necessary condition for the establishment of a stimulus as an effective cue to forget. At the present time, it does not seem possible to specify a critical condition that is both necessary and sufficient to the establishment of an effective cue to forget. It is possible, of course, that there is no such single condition. Perhaps the most appropriate strategy involves continued experimental analysis to determine conditions that

do and do not result in the establishment of an effective cue to forget.

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