

IRRELEVANCE OF SAMPLE STIMULI AND DIRECTED FORGETTING IN PIGEONS

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A successive matching procedure was used to investigate which aspect of the test-omission procedure is responsible for establishing a postsample stimulus as a cue to forget in pigeons. It was found that a postsample stimulus that reliably followed a sample that was irrelevant to performance functioned as a cue to forget. This result was obtained regardless of whether termination of that postsample stimulus was followed by reinforcement or by the presentation of sample-independent discriminative stimuli. It was also found that a postsample stimulus that functioned as a cue to forget at the beginning of training lost that function when it was repeatedly presented on trials in which the sample was relevant to performance. These findings reveal that (a) neither a reduction in reinforcement rate nor the omission of the opportunity for discriminated responding is necessary to establish an effective cue to forget and (b) irrelevance of the sample to performance is a sufficient condition to establish a cue to forget. These results suggest that a postsample stimulus that is presented on trials in which remembering the sample is not reinforced differentially will come to set the occasion for not remembering the sample.

Key words: directed forgetting, remembering, differential reinforcement of remembering, adventitious reinforcement of remembering, stimulus control of remembering, delayed matching, sample irrelevance, key peck, pigeons

A number of studies have found that the act of remembering the sample stimulus in delayed matching with pigeons can be controlled by presentation of cues to remember and to forget (Colwill, 1984; Grant, 1981, 1984, 1986, 1988, 1989; Kendrick & Newman, 1984; Kendrick, Rilling, & Stonebraker, 1981; Maki & Hegvik, 1980; Maki, Olson, & Rego, 1981; Parker & Glover, 1987; Santi & Savich, 1985; Schwartz, 1986; Stonebraker & Rilling, 1981; Stonebraker, Rilling, & Kendrick, 1981). One training regime effective in establishing control over the act of remembering is the test-omission procedure (e.g., Grant, 1981; Kendrick et al., 1981; Maki & Hegvik, 1980; Stonebraker & Rilling, 1981). In the test-omission procedure, half the trials involve a test for sample memory and the remaining trials terminate

prior to the test for sample memory. The cue to remember the sample is presented following termination of the sample on trials in which a standard test for sample memory is presented. The cue to forget the sample is presented following termination of the sample on trials in which the memory test is omitted. Control over the act of remembering by the cues is revealed by reduced matching accuracy on occasional trials in which a memory test is presented on forget-cued trials, a phenomenon referred to as directed forgetting.

In the standard omission procedure, forget-cued trials differ from remember-cued trials in three ways: The samples are irrelevant to performance because different sample stimuli are not correlated with different reinforcement contingencies, there is no opportunity for discriminated responding, and reinforcement is not presented. The question as to which of these differences is responsible for the effectiveness of the omission procedure in establishing a cue to forget has received considerable empirical and theoretical analysis. Grant (1981) suggested that the critical aspect of the omission procedure that results in the establishment of an effective cue to forget is the first of these differences. Specifically, because the sample stimuli are not correlated with differ-

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ent reinforcement contingencies on forget-cued trials, remembering, as opposed to forgetting, which sample stimulus was presented is not differentially reinforced. The failure to differentially reinforce remembering should cause remembering to extinguish in the presence of the forget cue, resulting in the establishment of an effective cue to forget.

Although it is plausible to attribute the effectiveness of the omission procedure in establishing a cue to forget to the irrelevance of the sample to performance, other investigators have suggested that either reinforcement omission or omission of the opportunity for discriminated responding may be the critical factor. Maki (1981; Maki et al., 1981) has noted that the process of adventitious reinforcement may be sufficient to maintain the behavior of remembering the sample on forget-cued trials. If so, then the critical feature of the omission procedure that is responsible for the establishment of an effective cue to forget is that such trials terminate without reinforcement.

Finally, Rilling and his associates (Kendrick & Rilling, 1986; Rilling, Kendrick, & Stonebraker, 1984) have suggested that the critical feature of the omission procedure may be the omission of the opportunity for discriminated responding. Specifically, they suggest that the omission procedure results in an effective cue to forget because the omission of stimuli differentially correlated with reinforcement causes attention to shift away from the matching task and toward whatever events the bird attends to during the intertrial interval, resulting in rapid forgetting of the sample stimulus.

Empirical analysis to determine which aspect of the omission procedure is responsible for the establishment of an effective cue to forget has involved the assessment of the importance of omission of end-of-trial reinforcement and omission of the opportunity for discriminated responding. To evaluate the importance of omission of end-of-trial reinforcement, a number of studies have provided reinforcement on forget-cued trials during training. Kendrick et al. (1981) presented un signaled reinforcement (Experiment 2) or required birds to insert their heads into the magazine opening to obtain reinforcement (Experiment 3) on all forget-cued trials. Maki et al. (1981) presented a cross, which was equally likely to appear on the right and left side key across trials, on forget-cued trials. A

single peck on the key illuminated by the cross produced reinforcement. None of these procedures established an effective cue to forget.

Although the research of Kendrick et al. (1981) and Maki et al. (1981) suggests that the omission procedure results in an effective cue to forget because remembering the sample is not adventitiously reinforced rather than because remembering the sample is not differentially reinforced, other data challenge this notion. Using a successive matching procedure, Grant (1981) and Kendrick and Newman (1984) found that omitting end-of-trial reinforcement on forget-cued trials was not a necessary prerequisite for establishing an effective cue to forget. In successive matching, only a single stimulus is presented at testing. If the test stimulus matches the sample, the first response after a fixed interval elapses (usually 5 s) results in reinforcement. If the test stimulus does not match the sample, the test stimulus terminates in nonreinforcement after the fixed interval expires. Matching accuracy is measured by the relative rate of responding to positive test stimuli (i.e., number of responses to positive test stimuli divided by the number of responses to both positive and negative test stimuli).

Grant (1981) and Kendrick and Newman (1984, Experiments 1 and 3) used red and green as sample and test stimuli. A black dot on a white background (Grant) or a white triangle on a black background (Kendrick & Newman) was presented in place of the matching or nonmatching test stimulus on forget-cued training trials. After the expiration of the normal test stimulus interval, response-independent reinforcement was presented with a probability of .5. It should be noted that, in the successive matching procedure, the probability of a remember-cued trial terminating in reinforcement is .5 because the test stimulus is equally often matching (and hence the trial terminates in reinforcement) and nonmatching (and hence the trial terminates in nonreinforcement). Thus, the condition in which the substitute stimulus terminates in reinforcement on 50% of the occasions equates probability of reinforcement on remember- and forget-cued trials. Both Grant and Kendrick and Newman established an effective cue to forget using this procedure.

The results of Kendrick et al. (1981) and Maki et al. (1981), obtained in the choice matching procedure, suggest that a necessary

prerequisite to establishing an effective cue to forget is that trials in which the forget cue is presented are less likely to terminate in reinforcement than are those in which the remember cue is presented. On the other hand, the results of Grant (1981) and Kendrick and Newman (1984), obtained in the successive matching procedure, suggest that forget-cued trials need not be less likely to terminate in reinforcement than remember-cued trials. Although the factor or factors responsible for discrepant results in the two matching procedures have not been identified, the pattern of findings is orderly in that the type of matching task employed determines whether or not reduction in reinforcement rate is important to the establishment of an effective cue to forget.

This state of empirical orderliness is challenged by recent results obtained by Kendrick and Newman (1984) and Schwartz (1986). Kendrick and Newman (Experiment 2) incorporated the single-stimulus substitution test described above into a choice matching procedure. Remember-cued trials terminated in a standard choice test involving matching and nonmatching comparison stimuli presented on the side keys. Forget-cued trials terminated in presentation of a white triangle on the center key for 6 s. Termination of the triangle was followed by food on 50% of the occasions for some birds and on 100% of the occasions for other birds. Subsequent testing revealed that each procedure resulted in the establishment of an effective cue to forget. In accord with this result is Schwartz's (Experiment 2) finding of reduced accuracy in a choice matching procedure on "delay trials" even though such trials terminated in un signaled reinforcement on 80% of the occasions, a value approximately equivalent to the reinforcement rate on remember-cued trials.

The results of Kendrick and Newman (1984) and Schwartz (1986) suggest that a reduction in probability of reinforcement on forget-cued trials during training is not a necessary prerequisite to the establishment of an effective cue to forget in the choice matching procedure. It appears at present, therefore, that a reduction in probability of reinforcement on forget-cued trials during training is not a necessary prerequisite to the establishment of an effective cue to forget in either choice or successive matching procedures.

The role of discriminated responding in establishing an effective cue to forget has also

been investigated. Neither the standard omission procedure nor any of the substitution procedures described above provided an opportunity for discriminated responding on forget-cued trials during training. It is possible, therefore, that the critical feature of the omission procedure that results in the establishment of an effective cue to forget is not that the sample is irrelevant to performance on trials in which the forget cue is presented but rather that discriminated responding is not required. A number of studies, employing both choice (Kendrick et al., 1981, Experiments 1 and 4; Maki & Hegvik, 1980, Experiment 2) and successive (Kendrick & Newman, 1984, Experiment 3) matching procedures, have presented sample-independent discriminative stimuli on forget-cue trials during training. In none of the four experiments was an effective cue to forget established, suggesting that the critical feature of the omission procedure resulting in the establishment of an effective cue to forget is the omission of the opportunity for discriminated responding.

Schwartz (1986, Experiment 2) found reduced matching accuracy on "forget trials" even though on such trials discriminated responding was required. Schwartz's interest focused on the analysis of sequential behavior rather than on the analysis of directed forgetting and, therefore, his procedure was rather different from that used in typical directed forgetting experiments. On forget trials, a sample, accompanied by the forget cue, was presented at trial onset. To advance to the next trial, which might be a "nonforget trial" and hence might involve reinforcement, the bird had to correctly perform a sequential operant; it had to peck each of the side keys, which were illuminated by the sample stimulus, exactly four times in any order. Neither a matching test, a substitute test, nor reinforcement was presented on forget trials during training. Of interest from the present perspective is the finding that, in spite of the fact that discriminated responding was required on forget-cued trials, matching accuracy was reduced substantially on forget-cued probe trials during subsequent testing. Because of the marked differences between the procedure employed by Schwartz and that used in other studies investigating the role of discriminated responding in directed forgetting, the implications of Schwartz's result for the issue of the role of discriminated responding in directed forgetting are unclear. For exam-

ple, one might appeal to the fact that forget trials terminated in nonreinforcement in explaining Schwartz's result although, as noted above, recent evidence has questioned the importance of this factor. Alternatively, one might appeal to the fact that the discriminated responding required in Schwartz's experiment involved performing a sequential operant during the sample presentation phase. In contrast, prior work showing that an effective cue to forget is not established if discriminated responding is required involved presentation of sample-independent discriminative stimuli at the time at which a memory test would normally be presented (Kendrick et al., 1981; Kendrick & Newman, 1984; Maki & Hegvik, 1980).

In our view, a reexamination of the question as to which aspect of the omission procedure is critical to the establishment of an effective cue to forget is warranted. This view is encouraged, in part, by the research considered above that questions the importance of reduction in reinforcement rate (Grant, 1981; Kendrick & Newman, 1984; Schwartz, 1986) and the opportunity for discriminated responding (Schwartz, 1986). Also encouraging such a reexamination is that in three of the four experiments in which discriminative stimuli were presented on forget-cued trials (Kendrick & Newman, 1984, Experiment 3; Kendrick et al., 1981, Experiment 4; Maki & Hegvik, 1980), subsequent testing revealed a moderate reduction in accuracy ranging from 6 to 8 percentage points (or discrimination units in the successive procedure). In the remaining case (Kendrick et al., 1981, Experiment 1), accuracy on forget-cued trials exceeded that on remember-cued trials by about 2 percentage points. Considering all four experiments collectively, there was a tendency toward reduced accuracy on forget-cued trials when such trials terminated in presentation of sample-independent discriminative stimuli.

An additional factor encouraging a reexamination of the question as to which aspect of the omission procedure is critical to the establishment of an effective cue to forget is recent research showing that, under conditions in which responding to a forget-cued sample results in a reduction in rate of reinforcement, an effective cue to forget can be established even though these trials typically terminate in reinforcement and involve discriminated re-

sponding (Colwill, 1984; Grant, 1986, 1989). Although these studies differ from typical substitution procedures in that forgetting a forget-cued sample increased the probability that the trial would terminate in reinforcement, it is nonetheless unclear why reduction in rate of reinforcement and/or the omission of discriminative stimuli should be necessary to the establishment of an effective cue to forget under some conditions but not others.

The present experiments were designed to determine which of the three aspects that differentiate remember-cued trials from forget-cued trials in the standard omission procedure is critical to the establishment of an effective cue to forget. This was accomplished by employing a successive matching procedure in which two groups of pigeons were tested in an ABA design. In Condition A, the sample was relevant to performance on trials in which the sample was followed by a vertical line, because on these trials a matching or nonmatching test stimulus was presented. On the other hand, the sample was irrelevant to performance on trials in which the sample was followed by a horizontal line, because on these trials a matching or nonmatching test stimulus was not presented. Instead, a triangle and a circle were presented following termination of the horizontal line. For birds in group nondifferential, a single response to either of these stimuli produced a reinforcer. For birds in group differential, a single response to one ($S+$) of these stimuli always produced a reinforcer and a single response to the other ($S-$) always produced only the intertrial interval.

Because the sample was irrelevant to performance on trials in which the horizontal line followed the sample, the horizontal line should function as a cue to forget in both groups if irrelevance of the sample to performance is the critical aspect of the omission procedure responsible for the establishment of an effective cue to forget. If, on the other hand, reduction in rate of reinforcement is critical, then the horizontal line should not function as a cue to forget in either group. This is the case because a trial in which the horizontal postsample was presented was more likely to terminate in reinforcement during training ($p = 1.0$ in group nondifferential and $p \approx 1.0$ in group differential) than was a trial in which the vertical postsample was presented ($p = .5$). Finally, if the lack of opportunity for discriminated re-

sponding is critical, then the horizontal line should function as a cue to forget in group nondifferential but not in group differential.

Condition B was identical to Condition A with the exception of the contingencies in force when the triangle and circle were presented following the horizontal line postsample. In group nondifferential, a single response to either the triangle or the circle resulted in the immediate presentation of a matching or nonmatching test stimulus. In group differential, a single response to S+ produced the immediate presentation of a matching or nonmatching test stimulus whereas a single response to S- produced only the intertrial interval. The reinforcement contingencies typical in successive matching were in force during presentation of matching and nonmatching test stimuli. Because the sample was relevant to performance on trials in which the horizontal postsample stimulus was presented, the horizontal line should come to function as a cue to remember during Condition B.

METHOD

Subjects

Eight Silver King pigeons were maintained at 80% of their free-feeding weights. Sessions were conducted 6 days per week, and supplementary feeding of mixed grain was provided after each session, if necessary, to ensure maintenance of prescribed weights. On days when experimental sessions were not conducted, each bird was fed an amount of mixed grain sufficient to maintain its prescribed weight. Water and grit were always available in the home cage. Each bird had extensive prior experience in successive matching to sample involving red and green sample and test stimuli. None of the birds had served previously in any experiments involving directed forgetting nor had any of the birds been exposed to either a vertical or a horizontal line.

Apparatus

The birds were tested in eight 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 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 in 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 a microcomputer.

Procedure

Condition A. Condition A involved training sessions and testing sessions. Training sessions consisted of 96 trials; each trial within a session was followed by a 20-s intertrial interval. Each trial began with the 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 s. Termination of the preparatory stimulus was followed immediately by presentation of a red or green sample stimulus on the center key for 5 s. Termination of the sample was followed by presentation of a postsample stimulus, a vertical line or a horizontal line, on the center key for 1 s. Each of the four sample-postsample combinations was presented on 24 of the trials within each session.

Termination of the vertical postsample was followed immediately by presentation of a red or green test stimulus on the center key. The test stimulus was positive if it was the same color as the sample on that trial and was negative if it was different in color from the sample presented on that trial. If the test stimulus was positive, the first response to occur 5 s after illumination of the test stimulus terminated the test stimulus and produced a reinforcer (3.5 s access to grain) that was followed by the intertrial interval. If the test stimulus was negative, the test stimulus terminated after 5 s and a reinforcer was not presented (the intertrial interval was extended by 3.5 s). The test stimulus was equally often positive and negative on both red-sample and green-sample trials.

Termination of the horizontal postsample was followed immediately by illumination of the two side pecking keys, one with a white triangle on a black background and the other with a white circle on a black background. The spatial arrangement of these stimuli was equally often triangle-left/circle-right and circle-left/triangle-right. A single response on ei-

ther side key terminated both stimuli. For the 4 birds assigned at random to group nondifferential, a single response on either side key produced a reinforcer followed by the intertrial interval. For the 4 remaining birds assigned to group differential, a single response to one stimulus (S+) produced a reinforcer that was followed by the intertrial interval, and a single response to the alternate stimulus (S-) produced only the intertrial interval. For 2 of the birds, S+ was the triangle and S- was the circle; for the remaining 2 birds, S+ was the circle and S- was the triangle.

Testing sessions were identical with training sessions except that four probe trials were added. Testing session contained 100 trials; Trials 25, 50, 75, and 100 were probe trials. Probe trials were identical to training trials involving the horizontal postsample except that a matching or nonmatching test stimulus, rather than the triangle and circle, was presented. The test stimulus was presented on the center key, and the reinforcement contingencies were identical to those on trials involving the vertical postsample. Each of the four sample stimulus-test stimulus combinations (red-red, red-green, green-green, and green-red) was tested once in each probe session. The order in which the four probe trials occurred varied from session to session.

Condition B. Sessions consisted of 96 trials and were identical to the training sessions of Condition A with the exception of the contingencies in force in the presence of the triangle and circle on trials in which the horizontal postsample was presented. In Condition B, a response to the triangle or circle never resulted in presentation of the primary reinforcer (food access) and instead always (in group nondifferential) or often (in group differential) resulted in presentation of a matching or nonmatching test stimulus. Specifically, in group nondifferential, a single response to either the triangle or the circle produced the immediate presentation of a matching or nonmatching test stimulus on the center key. In group differential, a single response to S+ produced the immediate presentation of a matching or nonmatching test stimulus on the center key whereas a single response to S- produced only the intertrial interval. The contingencies in force during matching and nonmatching test stimuli on horizontal-postsample trials were the same as those in force during matching and

nonmatching test stimuli on vertical-postsample trials.

Sequence of conditions. All birds were first trained and then tested in Condition A. Following 108 training sessions, each bird received eight testing sessions. Each of Testing Sessions 2 through 8 was preceded by two training sessions. Following the eighth testing session, each bird was transferred to Condition B. Each bird continued training in Condition B until it met a two-component criterion, which consisted of four consecutive blocks of four sessions each in which (a) collapsed across the four blocks, the discrimination ratio on vertical-postsample trials was no more than .03 higher than that on horizontal-postsample trials and (b) in none of those four blocks was the discrimination ratio on vertical-postsample trials more than .05 higher than that on horizontal-postsample trials. As each bird met the criterion, it was returned to Condition A and received 40 sessions of training followed by eight sessions of testing. The eight testing sessions were conducted in a manner identical to that of the first testing phase in Condition A.

RESULTS

In the first Condition A training phase, 3 of the 4 birds in group differential (P292, P295, P298) quickly acquired the simple discrimination that replaced the matching test on trials in which the horizontal postsample was presented. Beginning in the third block of four sessions, these 3 birds responded to the S+ on virtually all occasions. The remaining bird in this group (P293) responded to the S+ 80% of the time from Block 3 to the end of training (Block 27). Three of the 4 birds in group nondifferential (P291, P296, P297) displayed a simple position preference in responding to the triangle and circle. Two of the birds (P291 and P297) always responded to the stimulus on the right side key, and 1 bird (P296) always responded to the stimulus on the left side key. The 4th bird (P294) always responded to the triangle when it was presented on the right key but was equally likely to respond to the triangle or to the circle when the triangle was presented on the left key.

The data of primary interest are the discrimination ratios (number of responses to matching test stimuli, excluding reinforced re-

sponses, divided by the number of responses to both matching and nonmatching test stimuli) obtained as a function of type of postsample stimulus in the testing phases in Condition A and during the criterion period in Condition B. These data are shown in Figure 1. In both the first and second testing phase in Condition A, in which the sample was irrelevant to performance on trials in which the horizontal postsample was presented, each bird in each group demonstrated higher matching accuracy on trials in which vertical followed the sample than on trials in which horizontal followed the sample. In the first testing phase in Condition A (left panel in each half of the figure), mean discrimination ratios on vertical-postsample and horizontal-postsample trials were .89 and .70, respectively, in group nondifferential, and were .82 and .63 in group differential. In the second testing phase in Condition A (right panel in each half of the figure), mean discrimination ratios on vertical-postsample and horizontal-postsample trials were .88 and .73, respectively, in group nondifferential and were .82 and .62 in group differential.

In Condition B, in which the sample was relevant to performance on trials in which the horizontal postsample was presented, accuracy on horizontal-postsample trials increased across blocks of four sessions, and each of the 8 birds met the criterion. Matching accuracy as a function of the type of postsample stimulus during the four criterion blocks is shown in the middle panel of each half of Figure 1 (the numbers preceded by "B" refer to the first and last block of criterion performance). There was no marked between-group difference in the number of blocks required to achieve the criterion; group nondifferential required a mean of 23.0 blocks of training and group differential required a mean of 20.3 blocks of training. Collapsed across the four blocks in which the criterion was met, mean discrimination ratio on vertical-postsample trials exceeded that on horizontal-postsample trials by less than .02 in each group.

Response rates to matching and nonmatching test stimuli as a function of type of postsample stimulus in the testing phases in Condition A are shown in Table 1. Rate of responding to matching test stimuli was affected only moderately by the type of postsample stimulus presented. Collapsed across the 8 pigeons, rate of responding to matching test

stimuli on trials in which the horizontal postsample was presented (169 responses per minute) was somewhat lower than on trials in which the vertical postsample was presented (207 responses per minute). Moreover, only 3 of the 4 birds in each group demonstrated this effect; the opposite result, a higher rate of responding to matching test stimuli on trials in which the horizontal postsample was presented than on trials in which the vertical postsample was presented, was obtained for 1 bird in each group (P294 in group nondifferential and P295 in group differential).

Rate of responding to nonmatching test stimuli, on the other hand, was affected strongly by the type of postsample stimulus presented. Collapsed across the 8 pigeons, rate of responding to nonmatching test stimuli was approximately 2.5 times higher on trials in which the horizontal postsample was presented (96 responses per minute) than on trials in which the vertical postsample was presented (39 responses per minute). In addition, all 8 birds responded at a higher rate to nonmatching test stimuli on trials in which the horizontal postsample was presented than on trials in which the vertical postsample was presented. Thus, reduced accuracy on trials in which the horizontal postsample was presented in Condition A resulted primarily from an increase in rate of responding to nonmatching test stimuli.

Response rates to the vertical and horizontal postsample stimuli during testing in Condition A (at which time the horizontal postsample functioned as a cue to forget) and during the four blocks in which criterion was met in Condition B (at which time the horizontal postsample functioned as a cue to remember) are shown in Table 2. In Condition A, birds in group nondifferential demonstrated no systematic difference in rate of responding to the two postsamples, whereas birds in group differential demonstrated a higher rate of responding to vertical than to horizontal. During the four blocks in which criterion was met in Condition B, each of the 8 birds responded to vertical at a higher rate than they had during testing in Condition A. In addition, birds in group nondifferential responded to horizontal at a lower rate in Condition B than in Condition A, whereas birds in group differential demonstrated no marked difference in rate of responding to horizontal in Conditions A and B.

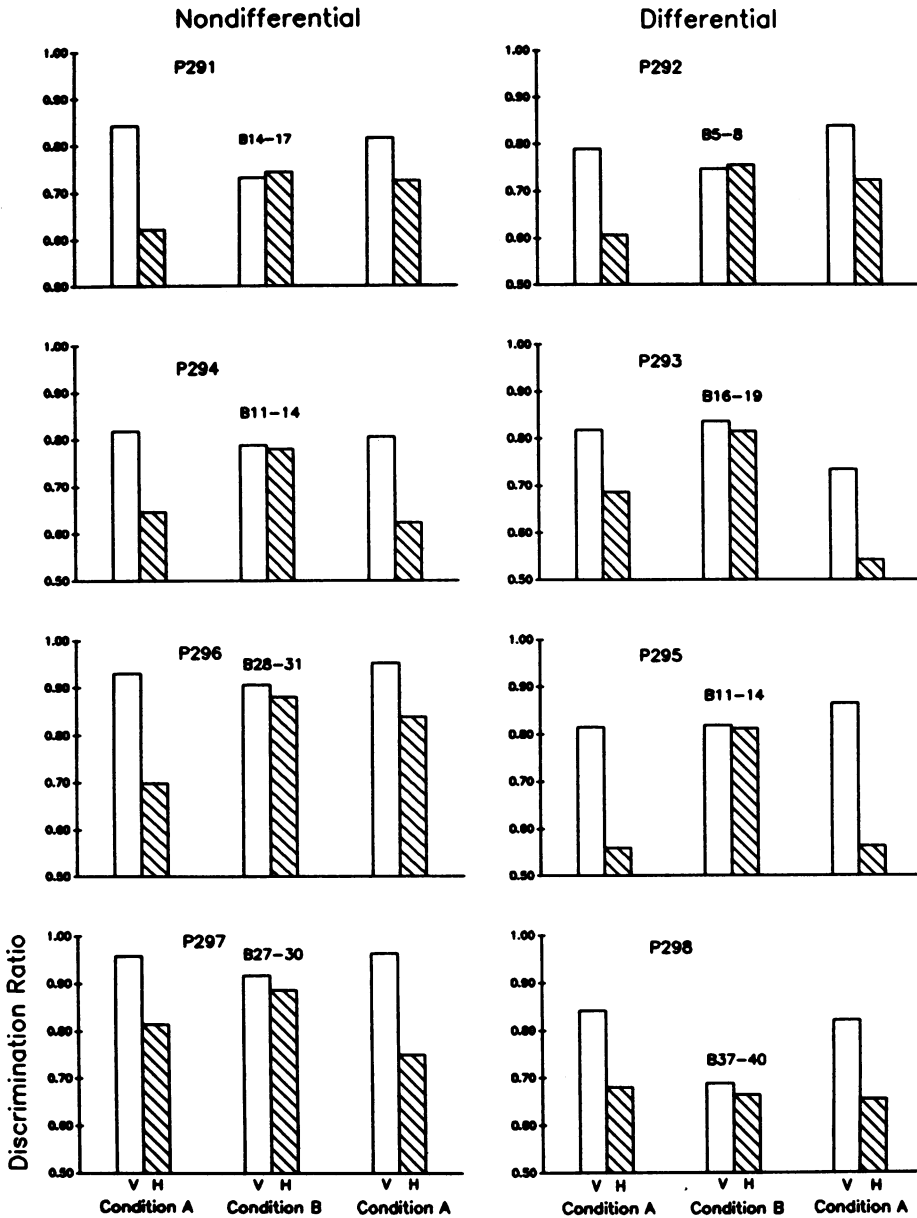


Fig. 1. Discrimination ratios as a function of type of postsample stimulus (V = vertical line, H = horizontal line) during the two phases of testing in Condition A and during the criterion period in Condition B. On trials in which the horizontal postsample was presented, the sample was irrelevant to performance in Condition A and was relevant to performance in Condition B. On trials in which the vertical postsample was presented, the sample was relevant to performance in both conditions.

DISCUSSION

The present experiment was designed to determine which of the three aspects that differentiate remember-cued trials from forget-cued trials in the standard omission procedure is critical to the establishment of an effective cue

to forget. In particular, interest focused on whether a reduction in rate of reinforcement or the omission of discriminative stimuli is necessary to the establishment of an effective cue to forget. This was accomplished by implementing a condition (Condition A) in which the sample was irrelevant to performance on

Table 1

Mean key pecks per minute to matching and nonmatching test stimuli in Condition A as a function of the type of postsample stimulus. Data from the first and second testing phases in Condition A have been combined.

Group nondifferential					Group differential				
Bird	Matching		Nonmatching		Bird	Matching		Nonmatching	
	Ver	Hor	Ver	Hor		Ver	Hor	Ver	Hor
P291	291	203	53	156	P292	167	101	37	48
P294	204	220	46	130	P293	232	182	70	112
P296	204	178	13	61	P295	106	113	20	90
P297	158	138	7	36	P298	290	212	59	129
<i>M</i>	214	185	30	96	<i>M</i>	199	152	47	95

Note: Ver = vertical line postsample stimulus; Hor = horizontal line postsample stimulus.

trials in which a horizontal line was presented as a postsample stimulus. However, such trials always terminated in reinforcement for some birds (group nondifferential) and always involved discriminated responding for other birds (group differential). The finding that the horizontal line functioned as an effective cue to forget for birds in group nondifferential in Condition A is consistent with other findings (Grant, 1981; Kendrick & Newman, 1984; Schwartz, 1986) in demonstrating that a reduction in rate of reinforcement is not necessary to the establishment of an effective cue to forget. The most important result from the present experiment is that the horizontal line also functioned as an effective cue to forget for birds in group differential in Condition A. This result demonstrates that the omission of the opportunity for discriminated responding is not necessary to the establishment of an effective cue to forget.

By demonstrating the nonnecessity of a reduction in rate of reinforcement and the omis-

sion of the opportunity for discriminated responding, the present results support the notion that irrelevance of the sample to performance is sufficient to establish a postsample stimulus as an effective cue to forget. Moreover, this condition was found to be sufficient regardless of whether that postsample stimulus was initially neutral (first Condition A) or initially functioned as a cue to remember (second Condition A). The results from Condition B provided further support for the notion that irrelevance of the sample to performance is the critical aspect of the omission procedure responsible for the establishment of an effective cue to forget. All aspects of the procedure in Condition B were kept as similar as possible to those in Condition A within the constraint imposed by the requirement that the sample was relevant to performance in Condition B. The finding that the horizontal line lost effectiveness as a cue to forget in Condition B, in spite of the procedural similarities between Conditions A and B, provides further evidence

Table 2

Mean key pecks per minute to the vertical and horizontal postsample stimuli collapsed across the two testing phases in Condition A and during the criterion blocks in Condition B.

Group nondifferential					Group differential				
Bird	Condition A		Condition B		Bird	Condition A		Condition B	
	Ver	Hor	Ver	Hor		Ver	Hor	Ver	Hor
P291	180	84	190	51	P292	167	54	250	57
P294	139	215	213	124	P293	169	23	250	39
P296	210	228	238	199	P295	127	57	141	22
P297	95	90	168	76	P298	264	64	277	69
<i>M</i>	156	154	202	113	<i>M</i>	182	50	230	47

Note: Ver = vertical line postsample stimulus; Hor = horizontal line postsample stimulus.

of the importance of irrelevance of the sample to performance in establishing an effective cue to forget.

The finding that the effectiveness of the horizontal postsample as a cue to forget was manifested primarily as an increase in rate of responding to nonmatching stimuli permits rejection of the rather uninteresting possibility that the horizontal postsample reduced matching accuracy in Condition A because it directed attention toward the side keys (where the triangle and circle were presented) and away from the center key (where the matching or nonmatching test stimuli were presented). If the horizontal line directed attention away from the center key, then rate of responding to both matching and nonmatching test stimuli should have been lower on trials in which the horizontal postsample was presented than on trials in which the vertical postsample was presented. The fact that rate of responding to nonmatching test stimuli was markedly higher on horizontal- than on vertical-postsample trials in Condition A is inconsistent with an attentional interpretation of the effectiveness of the horizontal postsample. It should be noted that other research employing the successive matching procedure has revealed that forgetting, whether induced by the presentation of a cue to forget (e.g., Grant, 1981; Stonebraker & Rilling, 1981) or by the passage of time in the absence of the sample (e.g., Nelson & Wasserman, 1978), is manifested primarily as an increase in rate of responding to nonmatching test stimuli.

In commenting on an earlier version of this article, J. Wixted (personal communication, April 3, 1990) suggested that the increase in rate of responding to negative test stimuli on forget-cued trials may be produced by failure to discriminate test stimuli from sample stimuli rather than by forgetting of the samples. The specific suggestion was that pigeons might react to the unexpected presentation of a test stimulus on forget-cued trials as the initiation of a new trial rather than as a memory test. Given the plausible assumption that pigeons typically respond at a higher rate to sample stimuli than to negative test stimuli, a tendency to confuse test and sample stimuli on forget-cued trials could explain the present results. Although this alternative account cannot be refuted definitively, we believe it is unlikely that the pigeons had difficulty in discriminat-

ing between sample stimuli (which were presented following termination of a 20-s inter-trial interval and the preparatory stimulus) and test stimuli (which were presented 1 s following termination of the sample and immediately following termination of the post-sample stimulus). It should be noted further that the majority of studies of directed forgetting have used a choice test (e.g., Colwill, 1984; Grant, 1986, 1989; Kendrick et al., 1981; Maki & Hegvik, 1980; Maki et al., 1981) that should minimize the possibility that pigeons might fail to discriminate test stimuli from sample stimuli. Nonetheless, it would be instructive to replicate the present experiment under conditions that would minimize the possibility that test stimuli might not be discriminated from sample stimuli. Such conditions might include the use of a symbolic or arbitrary matching task in which the samples and test stimuli are physically different stimuli and presentation of the test stimuli on a key different from that on which the samples are presented. Neither of these conditions was employed in the present experiment because use of a symbolic task would increase to nine the number of different stimuli required (i.e., preparatory stimulus, two samples, two test stimuli, two postsample stimuli, and two substitute stimuli) and because presentation of the test stimuli on a key different from the samples would introduce additional interpretative difficulties in that the test stimuli would be presented on the same key as the substitute stimuli (the triangle and circle). Given these considerations, perhaps the most effective way to enhance the discriminability of test and sample stimuli is to use different levels of ambient stimulation during sample and test stimulus presentation (e.g., houselight on during sample presentation and off during test presentation).

The question of why other experimenters have sometimes failed to establish an effective cue to forget when forget-cued training trials have terminated in reinforcement (Maki et al., 1981; Kendrick et al., 1981) or discriminated responding and reinforcement (Kendrick et al., 1981; Kendrick & Newman, 1984; Maki & Hegvik, 1980) should be considered. Although the present research was not designed to address this question, it should be noted that extensive training (108 sessions) preceded testing in the first Condition A. Although it is not possible to determine the number of training

sessions employed in many of the published studies on directed forgetting, we believe that the amount of training used in the present experiment is probably two or three times that which is typically provided. If so, then earlier failures to establish an effective cue to forget under conditions similar to those employed in group nondifferential and group differential may have been a product of insufficient training.

Indeed, it is reasonable to suggest that the amount of training required to establish a post-sample stimulus as an effective cue to forget is directly related to the extent to which the contingencies on forget-cued trials are similar to those on remember-cued trials. Consider that remembering the sample was differentially reinforced during initial noncued training in which all trials terminated in a test. When remember and forget cues were introduced subsequently, remembering the sample continued to be reinforced differentially on trials involving the remember cue but was not reinforced differentially on trials in which the forget cue was presented. The rate at which the act of remembering the sample comes under control by the postsample stimuli will presumably be a function of a number of factors, including the extent to which the contingencies in force in the presence of the forget cue permit the adventitious reinforcement of remembering. Because the omission procedure precludes the possibility of adventitious reinforcement of remembering on forget-cue trials, it is reasonable to anticipate that an effective cue to forget would be established more rapidly in the omission procedure than in other similar procedures in which a reinforcer is presented at the end of forget-cued trials. Moreover, it is also reasonable to suggest that providing sample-independent discriminative stimuli might increase the likelihood that end-of-trial reinforcement would adventitiously reinforce the act of remembering the sample.

A second issue to consider is the suggestion by Rilling and his associates (e.g., Kendrick et al., 1981; Rilling et al., 1984) that postsample stimuli that promote remembering control high rates of key pecking during the interval between sample termination and test onset, whereas postsample stimuli that promote forgetting control low rates of key pecking during this interval. In the present experiment, the interval between sample termination and test

stimulus onset was occupied entirely by presentation of either the vertical or horizontal line. Because the horizontal line at times promoted remembering (at the end of training in Condition B) and at other times promoted forgetting (during testing in Condition A), the view of Rilling and his associates leads to the expectation that rate of responding in the presence of the horizontal line would be markedly higher in Condition B than in Condition A. This prediction was not confirmed, in that rate of responding to the horizontal line was actually somewhat lower in Condition B than in Condition A. Reduced responding to horizontal in Conditional B was probably caused by the fact that the horizontal line was correlated with a lower probability of end-of-trial reinforcement in Condition B (.5) than in Condition A (approximately 1.0). The reduced probability of end-of-trial reinforcement on horizontal postsample trials in Condition B relative to Condition A may also be responsible for the increase in rate of responding to the vertical postsample in Condition B. Specifically, positive behavioral contrast would be anticipated because rate of reinforcement decreased in one component of the procedure (trials on which the horizontal postsample was presented) and remained constant in the second component of the procedure (trials on which the vertical postsample was presented).

Rilling's suggestion also leads to the expectation that rate of responding to vertical (remember cue) would exceed that to horizontal (forget cue) in Condition A. Although this was the case for birds in group differential, it was not the case for birds in group nondifferential. Whether this between-group difference reflects individual differences or the effect of following the horizontal line by stimuli that were or were not differentially correlated with reinforcement was not evaluated in the present experiment. Nonetheless, the finding that at least some birds did respond at a higher rate to horizontal than to vertical in Condition A is inconsistent with the view that stimuli that promote remembering necessarily control higher rates of responding than do stimuli that promote forgetting. Thus, although postsample stimuli that promote remembering often control higher rates of key pecking than do postsample stimuli that promote forgetting, the present results suggest that this difference is not related causally to the different effects of

cues to remember and to forget on the act of remembering.

Considering the present results in conjunction with those of other recent studies suggests that two conditions are sufficient to establish a postsample stimulus as a cue to forget. The first, as revealed in the present experiment, is that the postsample stimulus reliably follow a sample that is irrelevant to performance. The second, as revealed in experiments reported by Colwill (1984) and Grant (1986, 1989), is that a postsample stimulus reliably follow a sample that, if it were to control performance, would result in a decrease in probability of reinforcement. Whether these two conditions are exhaustive of those sufficient to establish a postsample stimulus as a cue to forget warrants investigation.

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