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SHORT-TERM REMEMBERING OF DISCRIMINATIVE STIMULI IN PIGEONS

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Pigeons learned to peck the left or right of two white keys depending on whether a red or a green stimulus was displayed on a third key. The opportunity to peck the white keys was then delayed for zero to six seconds after the red or green (to-be-remembered) stimulus. On half the trials, the feeder operated during the delay to interrupt behavior that might mediate discriminated responding. No events were scheduled on the remaining trials. In a later condition, the pigeons had the opportunity to peck the white keys during the delay. In general, accuracy decreased as delay increased in all conditions, but performance was least accurate following feeder operations and most accurate when pecking was allowed during the delay. The procedures may be analogous to varying the opportunity for rehearsal in studies of human short-term memory.

Key words: remembering, memory, short-term memory, rehearsal, delay, stimulus control, discrimination, key peck, pigeons

Remembering is behavior. An episode of remembering must include at least three components: the presentation of some stimulus; an intervening time period or delay; and then an opportunity for some discriminative response under the control of the absent stimulus. In the language of human memory research, these components are respectively called storage, retention, and retrieval (cf. Catania, 1979, Chapter 13). The organism is said to store the item to be remembered, to retain it over the delay, and then to retrieve it at the time of recall. If the stimulus occasions some behavior during the delay that increases the likelihood of recall, that behavior is sometimes referred to as rehearsal. Rehearsal need not be verbal (e.g., Wagner, Rudy, & Whitlow, 1973), although verbal rehearsal is a common feature of human remembering.

Early studies of human short-term remembering ordinarily used stimuli within the span of immediate memory, such as consonant trigrams, and required behavior during the delay that interfered with rehearsal, such as counting backwards by threes (e.g., Peterson & Peterson, 1959; Waugh & Norman, 1965). Accuracy of recall declined substantially over delays of 6 to 12 sec with these procedures (Keppel & Underwood, 1962; Melton, 1963; Murdock, 1961).

Several studies have been designed to extend the analysis of short-term remembering to pigeons. In general, the pigeons's accuracy of recall declined with time since the stimulus in these and related procedures, from accurate recall with no delay to near-chance levels with delays of about 3 to 5 sec (e.g., Farthing, Wagner, Gilmour, & Waxman, 1977; Grant & Roberts, 1976; Roberts, 1972; Shimp, 1976; Shimp & Moffitt, 1974, 1977; but cf. Berryman, Cumming, & Nevin, 1963; Nelson & Wasserman, 1978). On the basis of only the quantitative relation between accuracy and delay, the pigeon data seem analogous to those from humans. But the quantitative similarity does not guarantee an equivalence in behavioral process (cf. D'Amato & Cox, 1976). The studies of human and pigeon remembering differ along a variety of dimensions. Among these are the type and number of stimuli to be remembered and the number of times each organism and stimulus is tested. These proce-

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dural differences follow from differences in the behavior repertories of humans and pigeons, and thus cannot easily be reconciled.

An assumption probably implicit in extant studies of short-term remembering in pigeons is that, because pigeons do not engage in verbal behavior, there is no need to prevent rehearsal during retention. Evidence of some researchers' tendency to generalize between human and pigeon studies of short-term memory is in the similarity of the properties ascribed to both (e.g., effects of unexpected stimuli on rehearsal processes, and limited storage capacity: cf. discussion in Tranberg & Rilling, 1980). But various types of behavior during the delay could facilitate accurate responding (e.g., Blough, 1959; Ferster, 1953). Some studies have interpolated stimuli such as houselights during the delay between the to-be-remembered stimulus and the pigeons' opportunity to respond (Grant & Roberts, 1976; Shimp & Moffitt, 1977; Zentall, 1973), with varied effects. Reductions in accuracy produced by such procedures have typically been discussed in the context of retroactive interference, by analogy to studies of human remembering in which the learning of a new task interferes with recall of an earlier task (e.g., Baddeley, 1972; cf. Williams, 1975). Accounts in terms of retroactive interference and in terms of rehearsal may be compatible, however; retroactive interference may come about because responses occasioned by interpolated stimuli displace responses that would otherwise have remained under the control of the to-be-remembered stimulus.

In any case, by analogy with the procedural aspects of experiments on human short-term memory, rather than by analogy with the quantitative details of the function relating accuracy to delay, the present research varied the control of the behavior that occurred during the delay between the to-be-remembered stimulus and the pigeon's response. In Experiment 1, the feeder was operated during the delay on half the test trials, so that standard performance could be compared with performance in which the activity of eating was interpolated into the delay. If rehearsal occurred in standard trials, its nature was unspecified but it is reasonable to assume that it was disrupted in activity trials. In Experiment 2, a third procedure was added that provided a more explicit opportunity for responding analogous to rehearsal during the delay.

METHOD

Subjects

Three male Silver King and one male White Carneau pigeons were maintained at 80% of free-feeding weights. The White Carneau (Bird 9) had an extensive experimental history, but the Silver Kings were exposed only to an autoshaping procedure.

Apparatus

Daily sessions were conducted in a standard chamber with three translucent Gerbrands keys mounted 6.5 cm apart, center-to-center, in an equilateral triangle. Two keys 23.5 cm from the floor formed the base of the triangle. A 5-cm-square opening centered below the keys and 7.5 cm from the floor allowed access to 3-sec deliveries of food from a Gerbrands mixed-grain feeder.

The to-be-remembered stimuli (red or green) were projected on the key at the apex of the triangle. At the outset, pecks to these stimuli had no scheduled consequences. The two keys at the base of the triangle, occasionally lit white, served as response keys. One peck to either key produced either reinforcement or timeout.

A houselight was lit except during reinforcement and timeout. A fan provided continuous ventilation. A small eyepiece on top of the chamber, similar to those installed in apartment doors, allowed periodic observation of the birds. Standard electromechanical scheduling and recording equipment was located in a separate room.

Procedure

All sessions included 80 trials; only the first peck per trial was recorded, each peck on a response key was followed by 3 sec of either reinforcement or timeout, and the time between successive stimulus onsets was held constant at 30 sec.

Training. In the first session, the response keys were randomly lit, one per trial, over an equal number of trials, to establish pecks on both. To-be-remembered stimuli were not presented during this session. Simultaneous discrimination training began on the second session. The to-be-remembered discriminative stimuli, red and green, were correlated with the availability of reinforcement for pecks on either the left or right response key. For Birds

9 and 48, a red stimulus indicated availability of reinforcement for pecking the left key and a green stimulus indicated availability of reinforcement for pecking the right key. For Birds 41 and 45, this relation was reversed.

After 10 sessions with accuracy at chance levels for all birds, an observing response was added. Each trial began with the key at the apex of the triangle lit white. The first peck on this key changed its color to red or green and lighted the two response keys white. Each stimulus was presented equally often in the same irregular sequence as that of the first session. Correct pecks produced a 3-sec reinforcer; incorrect pecks produced a 3-sec timeout. No correction procedure was used. Training continued until a criterion of at least 95% correct responses was attained. The number of sessions to reach criterion was 11, 12, 33, and 26 for Birds 9, 41, 45, and 48, respectively.

The first 20 trials of the first session after criterion continued as in simultaneous discrimination training, with the modification that the stimulus was turned off 3 sec after onset instead of remaining on until the bird pecked. This modification had minimal effect, as all birds were responding within 3 sec. Over the next 60 trials, onset of the response key lights was gradually delayed until the procedure had shifted from simultaneous discrimination training to a 0-sec delay between the discriminative stimulus and the availability of response keys.

Accuracy decreased to near-chance levels for all birds during the 0-sec delay procedure. After several sessions, accuracy returned to the 95% criterion. Birds 9, 41, 45, and 48 reached this criterion respectively in 8, 2, 10, and 2 sessions.

Experiment 1. For the first 40 trials of subsequent sessions, a 0-sec delay was in effect. If the birds responded with 95% accuracy during these trials, a delay greater than 0 sec was arranged for the remaining 40 trials. If accuracy was less than 95%, the 0-sec delay continued for the rest of the session. Accuracy was tested after delays of .5, 1, 2, 4, and 6 sec. The decision to obtain data at .5 and 6 sec was made after data from 1, 2, and 4 sec were available. Each duration was tested during two separate sessions, in the order shown in Table 1.

For half of the test trials in each session no events were scheduled during the delay interval; all key lights were off and the houselight remained on. These were *standard* trials. For the other half, the houselight was turned off and the feeder and feeder light were operated throughout the delay. These were *activity* trials. Standard and activity trials alternated irregularly according to the repeating sequence: OOXO XXOO OXXO OXXX OOXX OXXO OXOO OXXO OXXX, where the sequence began at a different point for each bird and session, and the assignment of O and X to the red and green to-be-remembered stimuli was occasionally reversed from one session to the next.

Experiment 2. The contingencies for reinforcement and timeout and the time between successive stimulus onsets continued as in Experiment 1. Sessions were discontinued for Bird 48 before the onset of Experiment 2 because of illness and variable performance. For Birds 9, 41, and 45, several sessions of 0-sec delay were conducted between Experiments 1 and 2 and between conditions in Experiment 2 to ensure stable performance. Accuracy after the same five durations as in Experiment 1 was tested under three successive conditions. A 0-sec delay was again in effect for the first 40 trials of each test session. If accuracy was 95% or better during these trials, a delay duration was in effect during the last 40 trials. The delays were scheduled in ascending order over successive sessions within a given condition.

Under the first condition, *rehearsal,* the response key lights were turned on during the delay, but pecks on either key during the delay had no scheduled consequences. The first peck after the delay ended produced the reinforcer or timeout, as appropriate. The procedure is equivalent to a fixed-interval schedule of reinforcement or timeout. Standard and activity trials, as in Experiment 2, respectively comprised the second and third conditions under which accuracy was tested. Only one condition and delay was in effect during any session, and each condition-delay combination was tested once.

RESULTS

Experiment 1. Figure 1 shows the percent correct responses in the standard and activity trials averaged over both test sessions at each delay. Data from individual sessions are presented in Table 1. A 0-sec delay was in effect for the first 40 trials of each session. One

Table 1

Orders of Delays and Percent Correct Responses in Individual Sessions of Experiment 1 for Each Pigeon

Bird 9	Delay (sec)	2.0	4.0	1.0	1.0	.5	4.0	2.0	6.0	.5	6.0
	Standard % Correct	90	50	90	80	100	75	60	45	100	50
	Activity % Correct	65	50	50	50	90	60	50	50	80	50
Bird 41	Delay (sec)	2.0	1.0	4.0	1.0	2.0	4.0	.5	.5	6.0	6.0
	Standard % Correct	55	75	60	70	55	70	90	90	65	65
	Activity % Correct	45	55	50	50	50	50	75	80	45	50
Bird 45	Delay (sec)	.5	1.0	2.0	4.0	6.0	6.0	4.0	2.0	1.0	.5
	Standard % Correct	80	70	50	45	40	57[a]	37[b]	65	70	90
	Activity % Correct	70	85	45	65	60	47[c]	45	50	40	75
Bird 48	Delay (sec)	1.0	2.0	4.0	4.0	2.0	1.0	6.0	.5	.5	6.0
	Standard % Correct	90	65	60	70	90	95	67[d]	100	90	75
	Activity % Correct	65	50	65	85	60	65	52[e]	85	100	65

Note: The number of test trials differed from the scheduled 20 trials in some sessions, as follows: a, 21; b, 19; c, 19; d, 18; e, 21.

nonzero delay was in effect for the remaining 40 trials, during which the standard and activity trials occurred equally often. Thus, each point for 0-sec delay is based on 400 observations, and each point for the nonzero delays is based on 40 observations.

Accuracy generally decreased as the delay interval increased and was higher during stan-

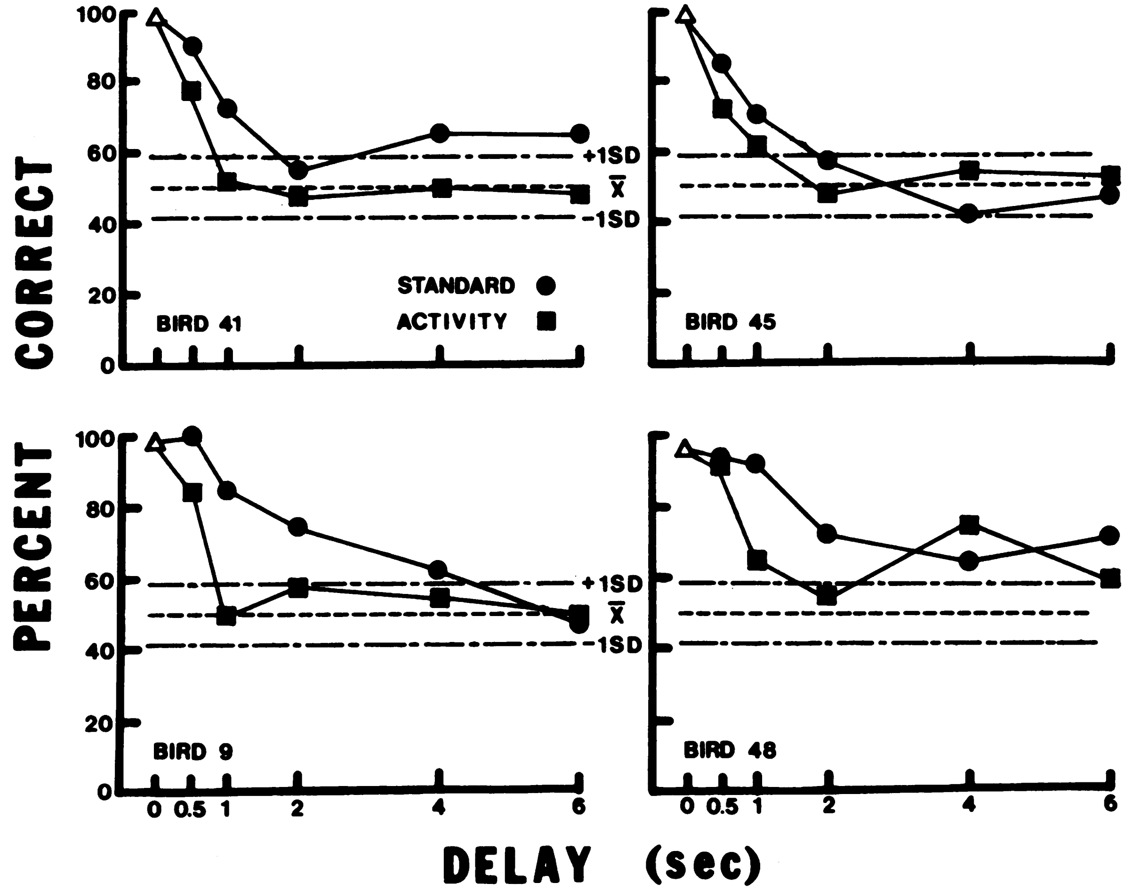

Fig. 1. Percent correct responses in standard and activity conditions as a function of delay interval (Experiment 1). The theoretical means (x) and standard deviations (SD) shown are based on the binomial distribution.

dard than during activity trials. All birds showed at least one reversal, but for the most part reversals occurred when discriminative responding was at near-chance levels. An exception was Bird 48, which showed greater accuracy during activity trials than during standard trials at the 4-sec delay.

Experiment 2. Figure 2 shows the percent correct responses in standard, activity and rehearsal trials as a function of delay duration. Each point for 0-sec delay is based on 200 observations, and those for the nonzero delays are based on 40 observations (i.e., one session). Except for one point (Bird 45, 6-sec delay), accuracy at a given delay during the activity condition was lower than accuracy during rehearsal and standard conditions. The reversal for Bird 45 occurred with discriminative responding at near-chance levels. Bird 45 and to a lesser extent Bird 9 responded more accurately during rehearsal than during standard conditions; Bird 41 showed virtually no difference between the two conditions. All birds pecked the response keys during the delay in both rehearsal and standard conditions but not in activity conditions; pecking typically began and continued on the response key appropriate to the to-be-remembered stimulus, and changeovers between the response keys were infrequent.

Sensitivity and bias. Discriminative control can diminish either because sensitivity to stimuli is reduced or because responding becomes biased toward one of the alternative discriminative responses. With complete bias to one response, sensitivity is indeterminate. A signal-detection analysis (e.g., Nevin, Olson, Mandell, & Yarensky, 1975) separates the contributions of sensitivity and bias to discriminated responding. Table 2 summarizes conditional probabilities (of hits and false alarms) at each delay under each condition for each pigeon. (The availability of only two points at each delay in Experiment 1 and three at each delay in Experiment 2 do not justify a graphical presentation.)

In Experiment 1, the reduced stimulus control at longer delays in activity relative to standard trials was accompanied by a left-key bias for Bird 9 and a right-key bias for Bird 41. Bird 45 showed a left-key bias in standard relative to activity trials at 2-sec and 4-sec delays. Bird 48 showed a lesser right-key bias in activity relative to standard trials at 1-sec delays.

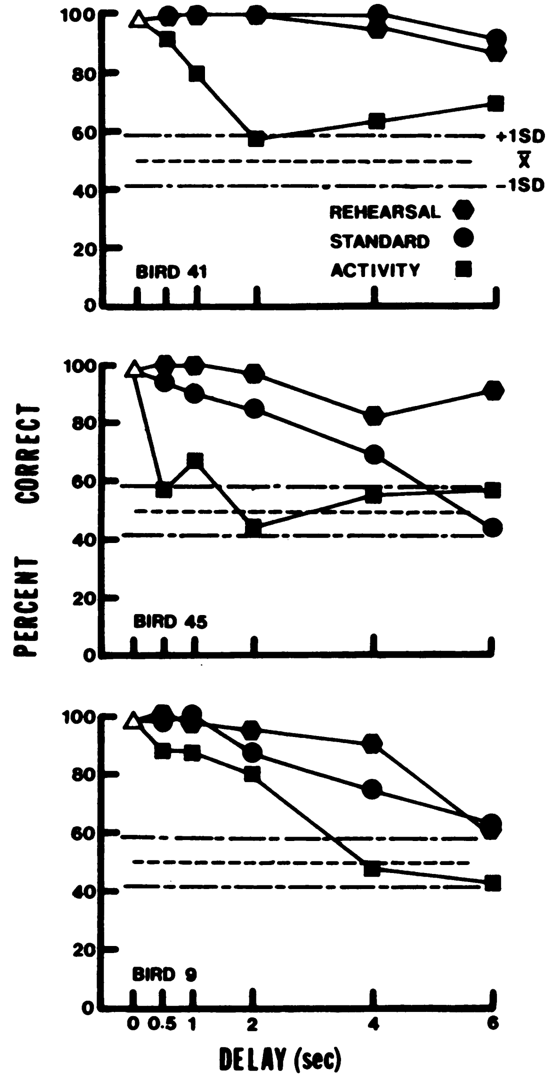

Fig. 2. Percent correct responses in rehearsal, standard and activity conditions as a function of delay interval (Experiment 2). The theoretical means (x) and standard deviations (SD) shown are based on the binomial distribution.

In Experiment 2, the reduced stimulus control at longer delays in activity relative to rehearsal and standard trials was not accompanied by systematic bias except in activity trials at 4-sec and 6-sec delays for Bird 45, when right-key responding predominated. In any case, given the ascending series of delays in each of the three conditions of Experiment 2, it is more likely that increases in bias were a consequence of diminished stimulus control than vice versa.

Table 2

Percent hits and false alarms (H/FA) at each delay in the standard (STD) and activity (ACT) conditions of Experiment 1 and in the rehearsal (REH), standard, and activity conditions of Experiment 2.

EXPERIMENT 1

Delay	*Bird 9*		*Bird 41*		*Bird 45*		*Bird 48*	
(sec)	*STD*	*ACT*	*STD*	*ACT*	*STD*	*ACT*	*STD*	*ACT*
0.5	100/00	85/15	86/05	80/25	90/20	70/25	90/00	90/05
1.0	75/05	100/100	65/20	10/05	65/25	55/30	90/05	35/05
2.0	65/15	90/75	25/15	00/05	100/85	45/50	65/10	65/55
4.0	40/15	90/80	55/25	00/00	80/100	30/20	45/15	75/25
6.0	45/50	100/100	50/20	00/05	62/65	74/65	68/26	52/35

EXPERIMENT 2

Delay	*Bird 9*			*Bird 41*			*Bird 45*		
(sec)	*REH*	*STD*	*ACT*	*REH*	*STD*	*ACT*	*REH*	*STD*	*ACT*
.5	100/00	100/00	80/05	100/00	100/00	100/16	100/00	91/00	30/15
1.0	95/00	100/00	80/05	100/00	100/00	78/17	100/00	80/00	55/21
2.0	95/05	100/25	85/25	100/00	100/00	30/15	95/00	70/00	15/25
4.0	95/15	65/15	70/75	90/00	100/00	79/52	80/15	77/38	10/00
6.0	80/55	35/10	35/50	70/00	85/00	58/20	82/00	25/36	20/05

Note: For Birds 9 and 48, hits were defined as correct left pecks given red stimuli and false alarms as incorrect left pecks given green stimuli; for Birds 41 and 45, hits were defined as correct left pecks given green stimuli and false alarms as incorrect left pecks given red stimuli. Thus, for all birds 100/00 implies perfect stimulus control, 100/100 implies complete left-key bias, and 00/00 implies complete right-key bias.

DISCUSSION

The data from standard trials in both experiments were consistent with previous findings (e.g., Roberts, 1972; Shimp, 1976; Shimp & Moffitt, 1974). The overall level of accuracy may have been lower in Experiment 1 than in Experiment 2 because of the shorter experimental histories or because standard and activity trials were both included within single sessions in the former case.

In activity trials, the operation of the feeder clearly interrupted or prevented some process that occurred in standard trials, when the feeder was not operated. In standard trials, there was little to compete with behavior that might have facilitated or mediated accurate responding (e.g., orienting in front of or looking at the appropriate response key). During activity trials, however, the birds oriented and moved toward the feeder, regardless of the discriminative stimulus. Feeder operations might have allowed the acquisition of relevant response patterns during the delay (e.g., approaching the feeder from the left or from the right), but the likelihood of such acquisition was undoubtedly lower than in standard trials.

Experiment 2 generally confirmed the results of Experiment 1, and demonstrated that pigeons can develop patterns of responding that facilitate remembering. When provided with the opportunity for overt rehearsal during delays (responding on the lit keys), all birds responded consistently above chance levels at all delays. Furthermore, all birds then pecked the dark response keys during delays in the subsequent standard trials; in other words, the behavior established in the rehearsal condition to a large extent transferred to the standard condition.

The purpose of the present studies is not to propose a model of short-term remembering in pigeons, but rather to distinguish between analogies with human short-term remembering based on the quantitative similarities of functional relations and those based on the correspondence of behavioral procedures. Rehearsal is behavior, but obviously the pigeon's rehearsal differs dramatically from that of a human, and the phenomena of human short-term remembering are more complex than those of the pigeon (at least in part because of the great variety of categories that humans remember; e.g., Wickens, 1970). This reservation applies both to quantitative analogies and to procedural ones. The vocabulary that has been developed in the context of human short-term memory should be extended only with caution to studies of short-term remembering in the pigeon, and procedures for preventing rehearsal should be included among the criteria for justifying such extensions.

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