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DELAY-INTERVAL ILLUMINATION CHANGES INTERFERE WITH PIGEON SHORT-TERM MEMORY

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Pigeons acquired a successive delayed matching-to-sample task at delay intervals ranging from 2.5 to 7 seconds. Test sessions were conducted during which delay-interval illumination conditions were changed from those illumination conditions that prevailed during the baselines. Compared to baseline delayed matching performance, changing delay-interval illumination disrupted matching. This disruption occurred whether the change in delay-interval illumination represented an increase or a decrease, relative to the baseline, and whether there was or was not a change in illumination during the test session. It was concluded that illumination per se introduced during delay intervals of delayed matching tasks does not interfere with pigeon short-term memory. Rather, a change in delay-interval illumination, relative to the baseline, appears to retroactively interfere in pigeon short-term memory.

Key words: delayed matching, short-term memory, retroactive interference, key peck, pigeons

In recent years, the delayed matching-to-sample (DMTS) task has enjoyed increasing attention as a paradigm for assessing animal short-term memory (D'Amato, 1973; Grant & Roberts, 1976; Maki, Moe, & Bierley, 1977; Roberts & Grant, 1976; Shimp & Moffitt, 1977). In two-choice DMTS, a delay intervenes between presentation of a sample stimulus and presentation of the comparison stimuli. A response to the comparison stimulus that matches the sample stimulus is required for reinforcement.

One variable that affects matching accuracy in DMTS is delay-interval illumination. The general finding is that illumination during the delay reduces accuracy of delayed matching compared to a baseline of delay-interval darkness whether the subjects are monkeys (D'Amato, 1973; D'Amato & O'Neil, 1971; Etkin, 1972) or pigeons (Roberts & Grant, 1976). Accuracy in DMTS is reduced by illuminated delays whether the samples are visual stimuli, different numbers of responses, or the occurrence vs. the nonoccurrence of reinforcement (Maki et al., 1977). The effect is very robust, often reducing accuracy of matching performance to chance levels whether the task is spatial or nonspatial (Etkin, 1972) or whether the source of delay-interval illumination is specific or ambient (Grant & Roberts, 1976). In addition, the amount of disruption in performance appears to be related to the total amount of interpolated illumination and not to the point of interpolation within the delay interval (Etkin, 1972; Maki et al., 1977; see, however, Roberts & Grant, 1978, for an exception to this finding).

Delay-interval illumination is generally interpreted as a source of retroactive interference. In some way, illumination during the delay interval retroactively interferes with an animal's memory for the sample stimulus. Explanations for the effect center around the degrading effects introduction of light per se has on retention. For example, D'Amato (1973) incorporated the effect into his temporal discrimination hypothesis by positing that visual events will be perceived as more recent after an interval spent in darkness than after an interval of identical length filled with a host of visual perceptions. The conclusion that memory for the sample stimulus following a dark delay is inherently superior to memory for the sample stimulus following an illuminated delay may not, however, be warranted. In the studies cited, it was always the case that during acquisition of DMTS and/or during DMTS training, prior to any manipulation,

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the delay interval was spent in darkness. The independent variable always involved an increase in delay-interval illumination. That is, baseline conditions in previous studies always included dark delay intervals and test conditions always included illuminated delay intervals. Consequently, sequence of exposure to delay-interval illumination conditions has not been adequately controlled.

It may be the case that if animals are trained in a delayed matching task with an illuminated delay interval and are subsequently tested with a dark delay interval matching will decrease to levels comparable to those which prevail when the opposite manipulation is conducted. The important variable may not be an increase in delay-interval illumination, but, rather, it may be a change in delay-interval illumination, relative to the baseline condition. The purpose of this experiment was to determine if a change in delay-interval illumination, either an increase or a decrease, disrupts DMTS performance.

A successive DMTS procedure was used in the present experiment. Successive DMTS is different from two-choice DMTS in several respects (Wasserman, 1976). Sample and comparison stimuli, in this case red and green discs, are presented on the same response key. Responses following matching trials (Red-Red and Green-Green) are reinforced whereas responses following nonmatching trials (Red-Green and Green-Red) are not reinforced. Rather than percentage correct, the dependent variable in successive DMTS is a discrimination ratio.

In the present experiment, birds were exposed to four different baseline and test conditions. The baselines were defined by the relationship between intertrial interval (ITI) and delay-interval houselight conditions. During training, the houselight was (a) on during the whole session, (b) on during the ITI but off during the delay, (c) off during the ITI but on during the delay, or (d) off during the entire session. The test conditions always involved a change, relative to the respective baseline, in delay-interval illumination. Two of the test conditions introduced increases, relative to the baselines, in delay-interval illumination, and the other two test conditions introduced decreases in delay-interval illumination. Furthermore, changes in illumination during test sessions were controlled. Of the two test conditions that increased delay-interval illumination, one condition included changes in illumination during the test session and the other had no changes in illumination during the test session. This was also the case for the test conditions that decreased delay-interval illumination. One of these test conditions had no change in illumination during the test session whereas the other did introduce a change in illumination during testing.

METHOD

Subjects

Seven adult White Carneaux pigeons, maintained at 80% of their free-feeding weights and housed individually in a temperature controlled and constantly illuminated room with constant access to grit and water, served. Pigeon 55 had previous experience in an autoshaping experiment.

Apparatus

The experimental space consisted of a homemade two-key operant conditioning chamber for pigeons. Inside dimensions were 30 cm by 30 cm by 34 cm. The two response keys were centered to the left and right above a 5- by 6-cm magazine opening. Only the left, 2.5-cm response key, which required a force of .15 *N* for activation, was used. The response key was transilluminated with either a red (606 nm) or green (555 nm) stimulus from an IEE projector (Model #0010-01-0393-44). The 28-V houselight (GE 757) was centered on the ceiling of the chamber within a translucent glass housing. During reinforcement, a 28-V light (CM 1829) within the magazine enclosure was illuminated. Activation of a Knight photoelectronic relay initiated the reinforcement timer. An exhaust fan, located on the front of a homemade soundproof enclosure, partially masked extraneous noises. Experimental events were controlled by standard electromechanical programming equipment located in an adjacent room.

Procedure

The six experimentally naive birds were trained to approach and eat mixed grain from the elevated food tray. Each bird was placed in the lighted test chamber with the food hopper elevated, lighted, and filled with mixed grain. When a pigeon inserted its head into the magazine opening, a photoelectric beam was broken and the food hopper was lowered after 2.5 sec. Magazine training continued for 30 2.5-sec food presentations separated by an ITI of 30 sec.

During the next 2 or 3 sessions, each bird was exposed to 60 autoshaping trials. The discriminative stimuli were either the red or green keylights and were programmed to occur equally often every 40 sec on a pseudo-random basis. Each stimulus lasted for 5 sec and was immediately followed by reinforcement. Throughout the entire experiment, reinforcement consisted of 2.5 sec access to mixed grain. Keypecks during autoshaping had no effect on the occurrence of reinforcement. If after a minimum of two autoshaping sessions, birds were reliably pecking both red and green stimuli, DMTS training began. If birds were not reliably pecking each stimulus after two sessions, an additional autoshaping session was given. All seven birds were reliably responding after a maximum of three autoshaping sessions.

Pigeons were placed on a successive DMTS task until performance stabilized at maximum delays individually tailored for each bird. Four types of trials were possible: Red-Red, Green-Green, Red-Green, and Green-Red. Stimuli were presented on a single key separated by the delay interval. Reinforcement and an associated blackout followed Red-Red and Green-Green trials. The first stimulus of each trial lasted a minimum of 5 sec and was terminated by a key peck after the 5 sec timed out. Following the delay interval, the second stimulus was presented for a minimum of 5 sec. If the stimulus was a match, a peck after the 5 sec resulted in reinforcement. If the stimulus was not a match, the blackout automatically occurred after the 5 sec elapsed. Sessions consisted of 96 trials, presented in a different pseudo-random order each session, with a 25-sec ITI separating each trial. Restrictions on the pseudo-random order were that no more than three reinforced or nonreinforced trials could occur consecutively.

During initial exposure to the successive DMTS procedure, a 1-sec delay interval was imposed on all birds. Birds continued with 1-sec delays until the discrimination was well formed and behavior was stable. After these criteria were reached, determined by visual inspection of the data, duration of the delay interval was increased in .5 to 1.0-sec increments until a maximum delay was reached for each bird. Birds were allowed a minimum of three sessions at each delay interval.

The independent manipulation was a change, relative to the baseline, in delay-interval illumination. Dependent on the test condition, this was accomplished by either turning the houselight on or off during test session delay intervals. Table 1 delineates the four experimental conditions as well as the birds that served in each. The number in parentheses next to each bird's number indicates order of exposure to the various conditions. Bird 55 served in all four conditions, Birds 2742 and 149 served in two conditions, and the remaining birds were exposed to only one condition. The illumination conditions during the ITI were identical to the illumination conditions during the sample and comparison stimuli. Three test sessions were conducted for each bird in each condition. Prior to the first test session in each condition, 5-day stable baselines were achieved. Following the first two test sessions of each condition, baseline conditions were reinstituted for single sessions.

Responses per min during each 5-sec stimulus, during the delay interval, and during the ITI were recorded during each session. Stimulus-terminating-responses during the first stimulus of each trial and reinforced responses were excluded from data analysis. The dependent variable of primary interest was a discrimination ratio determined by dividing

Table 1

Experimental design: houselight conditions during each baseline and test condition.

	Houselight		
	ITI	*Delay*	*Birds*[a]
Baseline	on	on	55(1), 5386(1), 2742(2)
Test	on	off	
Baseline	on	off	55(2), 2742(1), 149(1)
Test	on	on	
Baseline	off	off	55(3), 149(2)
Test	off	on	
Baseline	off	on	55(4), 389(1), 409(1)
Test	off	off	

Note. The houselight conditions during the sample and comparison stimuli were identical to the houselight conditions during the ITI for each condition.

[a] The numbers in parentheses after each bird's number indicate order of exposure to the experimental conditions.

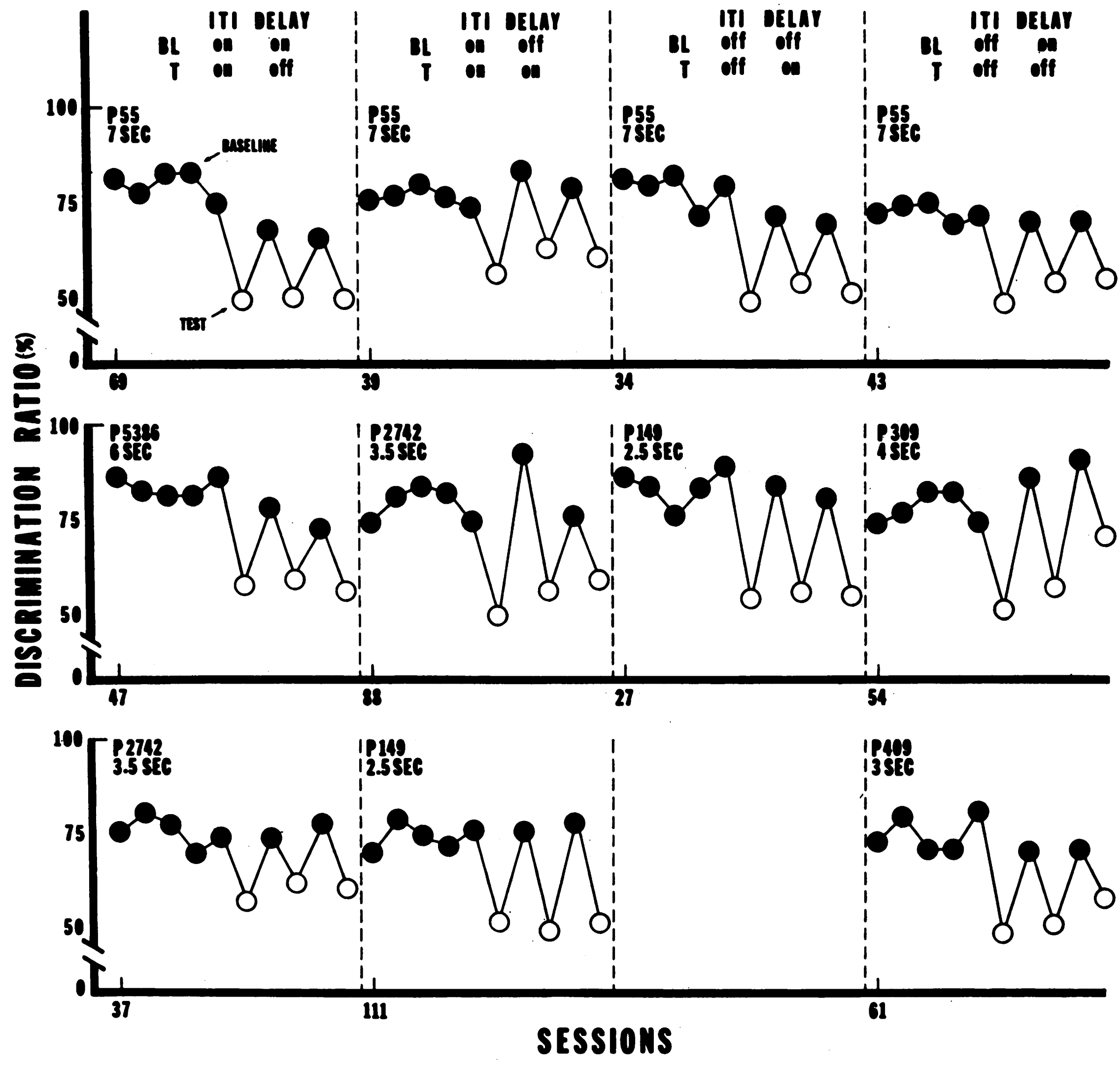

Fig. 1. Discrimination ratios for each bird during 5-day baselines, test sessions, and baseline recoveries for each of the four experimental conditions (BL = Baseline, T = Test session). The discrimination ratio shows percentage of total comparison stimuli responding that occurred during comparison stimuli of matching trials. A value of 100% indicates exclusive responding during matching trials; a value of 50% indicates equal responding on matching and nonmatching trials. The numbers on the horizontal axes correspond to the number of sessions a bird was in that particular houselight condition. The duration listed under each bird's number was that bird's delay interval.

response rate during the second stimulus of matching trials by response rate of both matching and nonmatching trials and multiplied by 100. An index of 100% indicates no responding on nonmatching trials; an index of 50% indicates equal rates of responding on matching and nonmatching trials.

RESULTS

Figure 1 shows discrimination ratios for each bird during 5-day baselines, test sessions, and baseline recoveries for each of the four experimental conditions. The duration listed under each bird's number was that bird's delay interval. The numbers on the horizontal axes correspond to the number of sessions of training birds received in each baseline condition. As is apparent in Figure 1, changing delay-interval illumination, relative to the delay-interval baseline condition, disrupted delayed matching performance for each bird in all four conditions. Thus, whether the change from

Table 2

Responses/minute: mean and standard errors for each bird in each condition during 5-day baselines and means during each session of the testing sequence.

	Houselight Conditions—Baseline: ITI On-Delay On								*Test: ITI On-Delay Off*				
Trial	*Red*	*Delay*	*Red*	*Green*	*Delay*	*Green*	*Red*	*Delay*	*Green*	*Green*	*Delay*	*Red*	*ITI*
Bird 55													
5-Day MN	107.1	388.8	345.5	133.8	394.1	389.6	112.6	384.2	117.1	108.8	389.0	75.5	6.6
Error	10.5	21.5	8.5	16.7	14.9	11.3	8.3	22.1	13.6	13.6	11.8	11.7	1.2
Test 1	114.0	17.9	314.5	85.0	22.5	342.0	135.0	18.6	341.0	102.0	25.0	335.0	8.0
Baseline	100.5	355.0	326.0	108.5	270.0	379.5	73.5	367.5	163.5	59.5	261.4	175.5	2.9
Test 2	121.5	16.1	283.5	50.0	18.2	370.5	60.0	19.6	342.5	70.5	19.3	300.5	4.0
Baseline	177.5	281.4	353.5	118.0	169.6	418.0	171.5	240.4	192.5	116.0	230.0	214.0	1.2
Test 3	135.5	17.1	361.0	125.0	16.4	327.0	104.0	13.9	327.0	91.0	15.4	378.5	0.1
Bird 5386													
5-Day MN	69.1	13.1	129.2	74.8	13.0	132.6	58.1	12.3	26.5	66.0	12.5	26.3	0.1
Error	2.2	0.6	12.9	8.3	0.7	11.4	2.7	0.7	3.2	5.0	0.6	4.2	0.0
Test 1	86.5	15.8	133.5	77.5	13.8	139.0	87.5	12.5	104.0	68.5	12.9	93.0	0.2
Baseline	79.0	12.9	87.5	65.0	14.6	108.0	65.5	11.7	16.0	55.0	12.5	36.5	0.3
Test 2	80.5	12.9	118.5	51.0	10.4	142.5	54.0	13.8	90.5	30.0	14.6	90.5	0.1
Baseline	35.5	11.2	70.5	65.0	15.4	111.0	47.5	12.9	36.5	48.0	17.5	32.5	0.2
Test 3	77.5	11.7	132.5	68.5	12.9	147.0	75.0	12.5	101.0	57.0	12.9	120.5	0.1
Bird 2742													
5-Day MN	113.7	198.4	213.1	93.3	205.4	228.3	98.4	221.3	81.9	82.9	200.0	73.0	10.2
Error	8.8	11.8	15.0	8.4	12.6	20.1	8.1	14.0	12.2	10.7	15.2	7.0	1.1
Test 1	115.0	35.7	293.5	101.5	35.7	249.0	125.0	36.4	244.5	82.5	33.6	162.0	23.4
Baseline	109.0	271.4	321.0	88.0	256.4	303.5	99.5	282.1	129.0	76.5	242.9	89.5	9.7
Test 2	114.5	31.4	278.5	67.0	27.9	277.5	113.0	31.4	146.0	81.5	32.1	197.5	5.0
Baseline	151.5	283.6	318.5	138.5	282.9	291.5	146.5	281.4	133.0	108.0	282.1	46.5	10.2
Test 3	145.5	33.6	302.5	105.5	31.4	304.0	109.0	25.0	191.0	118.5	32.9	209.0	11.9
	Houselight Conditions—Baseline: ITI On-Delay Off								*Test: ITI On-Delay Off*				
Bird 55													
5-Day MN	38.5	14.8	383.3	36.5	16.5	398.1	41.7	14.7	140.6	41.8	16.5	103.0	0.6
Error	3.8	1.9	13.8	10.0	0.5	10.4	5.5	1.3	17.1	9.9	1.6	14.5	0.2
Test 1	92.5	116.4	325.0	113.5	42.5	352.0	78.0	133.2	259.5	40.5	27.1	268.0	1.6
Baseline	66.5	22.1	399.5	67.5	24.3	374.5	46.0	24.3	94.5	50.0	21.8	57.0	0.7
Test 2	90.5	143.6	333.5	109.5	55.4	385.0	77.0	127.1	243.5	62.5	70.4	187.0	1.5
Baseline	168.5	13.6	361.0	121.0	15.0	382.0	195.5	16.4	125.0	100.0	15.0	79.0	0.4
Test 3	156.5	155.0	387.0	126.5	32.5	412.0	135.5	119.3	254.5	108.5	58.6	263.5	0.4
Bird 2742													
5-Day MN	66.1	19.3	155.5	74.8	19.9	146.5	59.0	18.6	37.7	68.4	18.9	44.2	5.1
Error	3.2	0.5	7.0	4.5	0.6	4.9	3.5	0.6	8.5	6.2	0.9	8.3	0.8
Test 1	45.0	65.7	116.5	74.0	64.3	134.0	41.0	72.9	156.5	64.5	61.4	99.5	4.5
Baseline	59.5	21.4	136.5	78.5	22.1	129.5	45.0	21.4	16.5	83.5	26.4	4.0	4.3
Test 2	108.5	146.4	183.5	147.5	140.7	212.5	113.0	127.1	198.5	145.0	95.7	110.5	5.5
Baseline	103.5	25.7	157.0	132.0	30.7	157.5	139.0	30.7	62.5	124.0	29.3	38.0	4.6
Test 3	142.0	95.0	212.0	121.5	78.6	243.0	155.0	125.0	174.5	100.0	61.4	141.0	3.6
Bird 149													
5-Day MN	101.6	93.8	96.5	102.7	93.4	132.1	115.2	95.8	32.8	109.1	98.4	46.5	0.4
Error	7.7	11.2	7.2	8.9	5.7	8.7	12.5	4.0	4.7	6.6	10.9	4.3	0.2
Test 1	118.5	130.0	144.5	130.0	110.0	164.0	113.5	110.0	144.0	132.0	112.0	145.0	0.8
Baseline	117.5	117.0	98.5	135.5	122.0	112.5	123.5	113.0	32.5	123.0	119.0	35.5	0.2
Test 2	70.5	96.0	135.5	114.5	75.0	141.0	80.5	106.0	151.5	115.5	97.0	135.0	1.0
Baseline	181.5	150.0	103.0	176.5	174.0	126.0	163.0	110.0	31.0	164.0	163.0	33.0	0.1
Test 3	190.5	98.0	146.0	178.0	99.0	154.0	190.5	88.0	128.5	196.5	77.0	156.5	3.5
	Houselight Conditions—Baseline: ITI Off-Delay Off								*Test: ITI Off-Delay On*				
Bird 55													
5-Day MN	52.7	205.1	367.9	80.4	111.4	344.4	53.3	196.1	102.8	49.9	113.8	92.2	4.5
Error	13.2	20.8	11.3	8.4	5.0	11.1	12.0	25.2	7.4	8.5	10.2	12.4	0.8
Test 1	136.0	45.7	282.5	157.0	40.0	303.0	130.0	52.9	337.5	180.0	24.6	273.5	8.4

Table 2 *continued*

Trial	*Red*	*Delay*	*Red*	*Green*	*Delay*	*Green*	*Red*	*Delay*	*Green*	*Green*	*Delay*	*Red*	*ITI*
Bird 55 cont'd.													
Baseline	196.5	178.6	369.0	143.0	98.9	380.5	159.5	172.5	130.0	150.5	88.9	177.0	5.2
Test 2	81.0	20.7	287.5	80.0	21.4	279.5	113.5	18.9	233.0	88.0	17.9	252.5	5.8
Baseline	102.0	185.4	365.0	133.5	89.6	342.0	106.5	148.9	177.5	88.5	77.5	133.0	2.8
Test 3	88.5	27.1	366.5	89.5	28.6	328.5	94.5	21.1	339.5	47.5	15.7	327.0	1.8
Bird 149													
5-Day MN	80.1	127.6	172.3	62.1	150.2	156.3	76.8	131.0	37.1	62.8	141.0	28.7	0.4
Error	10.1	12.6	16.3	7.7	12.1	16.5	8.6	15.1	6.4	11.7	9.0	5.3	0.2
Test 1	46.0	94.0	150.5	40.5	90.0	122.5	44.0	110.0	71.5	35.5	86.0	161.5	0.6
Baseline	75.5	151.0	156.0	49.0	139.0	152.0	61.5	139.0	33.5	63.5	162.0	26.5	0.0
Test 2	71.5	77.0	162.0	49.5	94.0	164.5	61.0	107.0	124.5	39.5	96.0	134.5	0.7
Baseline	57.5	151.0	143.5	57.0	219.0	134.0	59.0	180.0	44.0	41.5	195.0	23.5	0.4
Test 3	60.5	78.0	165.5	57.5	89.0	153.0	80.0	80.0	128.5	53.0	78.0	133.5	0.4
		Houselight Conditions—Baseline: ITI Off-Delay On							*Test: ITI Off-Delay Off*				
Bird 55													
5-Day MN	106.5	11.2	240.1	135.5	11.6	244.8	108.3	10.7	110.2	113.4	11.5	78.7	3.5
Error	8.6	0.6	10.2	13.3	0.6	5.9	8.1	0.3	5.8	15.0	0.6	13.1	0.4
Test 1	130.5	109.6	237.5	236.5	109.6	264.0	183.5	135.0	300.5	195.5	107.1	238.0	22.0
Baseline	189.5	15.7	238.0	196.5	13.2	272.0	187.5	16.1	115.0	158.5	11.1	106.5	7.5
Test 2	196.0	85.0	281.0	227.5	90.4	298.5	204.5	62.5	293.0	87.5	82.5	201.0	15.8
Baseline	156.5	12.1	280.5	207.5	14.6	300.0	167.0	12.1	122.5	167.5	13.2	125.5	3.2
Test 3	190.0	123.2	354.0	262.0	90.0	376.0	246.0	121.1	365.0	166.0	96.1	229.0	9.8
Bird 389													
5-Day MN	135.7	15.1	131.5	50.5	15.4	129.8	132.3	15.1	31.7	47.6	15.6	43.3	0.0
Error	20.1	0.2	18.6	6.8	0.5	11.9	17.0	0.3	8.1	7.0	0.4	6.4	0.0
Test 1	229.0	53.1	227.5	135.0	95.6	208.0	226.0	43.1	204.5	133.0	74.4	209.0	4.0
Baseline	210.5	18.1	180.5	119.5	15.6	130.0	184.0	17.5	21.5	111.0	17.5	27.5	0.4
Test 2	198.5	28.8	175.5	103.5	60.0	188.5	189.0	26.9	207.5	121.0	56.9	69.5	0.8
Baseline	145.0	16.9	137.5	96.0	17.5	145.0	149.5	13.8	21.5	148.0	18.1	7.0	0.0
Test 3	150.5	35.6	210.5	110.5	36.9	193.5	148.0	39.4	120.0	113.5	46.9	51.0	1.3
Bird 409													
5-Day MN	253.1	92.8	309.9	225.4	94.8	297.3	257.0	86.3	69.4	220.3	96.0	115.4	9.5
Error	5.0	5.5	8.6	2.7	5.7	4.2	4.5	6.8	7.9	6.0	7.9	21.2	0.5
Test 1	268.0	78.3	319.5	243.0	75.8	308.0	271.5	94.2	323.0	239.0	85.0	344.0	5.7
Baseline	237.5	86.7	342.0	229.5	100.0	318.5	224.5	77.5	140.0	225.0	93.3	139.0	3.7
Test 2	263.0	65.0	341.5	219.5	71.7	307.5	253.0	83.3	312.0	233.5	85.0	308.0	4.4
Baseline	243.0	75.0	316.5	243.0	86.7	312.5	232.0	80.8	228.0	263.0	85.8	33.5	6.4
Test 3	219.0	81.7	322.5	191.0	75.0	327.0	236.0	92.5	286.0	204.5	74.2	180.5	3.8

baseline involved an increase in delay-interval illumination (Columns 2 and 3) or a decrease in delay-interval illumination (Columns 1 and 4), delayed matching performance was worse relative to both the 5-day baselines and the baseline recoveries. This effect obtained whether the change from baseline involved a change in illumination during the test session (Columns 1 and 3) or did not involve change in illumination during the test session (Columns 2 and 4).

Table 2 presents mean responses/min and standard errors for each bird in each condition during 5-day baselines and mean responses/min during each session of the testing sequences. Table 2 indicates that the test session disruptions in delayed matching shown in Figure 1 may primarily be accounted for by large increases in rates of responding during the second stimulus of nonreinforced trials (Red-Green and Green-Red) rather than by a reduction in reinforced trial response rates (Red-Red and Green-Green). Relative to the 5-day baseline mean, the overall change in rate of responding on nonmatching trials during test sessions was an increase of 139.5 responses/min. This increase represents a 202.8% change from the baseline. This general pattern was evident in each of the four test conditions. The change in rate of responding during nonmatching trials ranged from an increase of 111.2 responses/min in the test condition when the houselight was always on to an increase of 160.8 responses/min in the test condition when the houselight was always off. Rate of responding on matching trials during test sessions did not substantially change. The overall change in rate on reinforced trials was an increase of 14.5 responses/min, a change of only 6.2%. The only exception to this pattern was test condition *off-on* (Column 3 in Figure 1). Both birds in this condition showed decreases in rate of responding on reinforced trials. The mean reduction in response rate for these two birds was 29.8 responses/min, a decrease of 11.5% from the 5-day baseline.

The slight disruption shown in the baseline recoveries in Figure 1 may also be primarily accounted for by increases, relative to the 5-day baselines, in nonreinforced trial responding. Analysis of Table 2 shows that during the baseline recovery sessions there was an overall increase of 15.4 responses/min (Range: −7.3 to +22.1 responses/min) on nonreinforced trials, a change of 22.4%, whereas during reinforced trials, response rates increased 6.9 (Range: −16.8 to +38.7 responses/min), only a 3% change from the baselines.

As is also shown in Table 2, changes in delay-interval responding during test sessions were correlated with matching-to-sample disruption. The best way to describe how delay-interval responding changed during test sessions is in relation to whether or not there were changes in illumination during the test sessions. Thus, the delay-interval responding of test session conditions *on-on* and *off-off* (Columns 2 and 4, respectively, in Figure 1) are considered together, and the delay-interval responding of test session conditions *on-off* and *off-on* (Columns 1 and 3, respectively, in Figure 1) are considered together. When there was not a change in illumination during test sessions there was a large increase, reliative to the 5-day baselines, in delay-interval responding whether the first stimulus of a trial was red or green. Following a red sample, there was an increase of 54.1 responses/min, a change of 132.9%. After a green sample, response rates increased 34.6 responses/min, a change of 81.6% from the baselines. In contrast, when test sessions did include changes in illumination there were large decreases in delay-interval response rates following both red and green sample stimuli. Following a red sample, a decrease of 150.9 responses/min in delay-interval responding was obtained, 80.4% lower than the 5-day baseline. Following the green sample, response rates decreased 137.5 responses/min, a 79.4% change.

These general patterns were quite consistent within individual birds. The only exception to the decreased rate of delay-interval responding obtained in the test sessions with changes in illumination was Bird 5386 in test condition *on-off*. This bird's rate increased .5 responses/min following a red sample and .1 responses/min following a green sample. The only exceptions to the trend of increased delay-interval rates in test conditions that had constant illumination conditions were Birds 2742 and 409. Bird 2742, in test condition *on-on*, showed a decrease of .9 responses/min following a green sample. In test condition *off-off*, Bird 409 showed decreases of 7.1 and 17.6 responses/min following, respectively, red and green sample stimuli.

These changes in rates of responding during test-session delay intervals may reflect the tendency of birds to respond at a high rate when there is not a change in illumination during a matching trial but to respond at a low rate when there is a change in illumination during the trial. Table 3 summarizes delay-interval responding as a function of each of the four experimental conditions during the 5-day baselines, test sessions, and baseline recovery sessions. As Table 3 shows, rates of responding were relatively high during the delays when illumination was constant throughout the session (baseline conditions *on-on* and *off-off* and test conditions *on-on* and *off-off*) whereas birds responded at a fairly low rate when there were changes in illumination during a session (baseline conditions *on-off* and *off-on;* test conditions *on-off* and *off-on*). The mean rates of responding when illumination conditions were constant were 171.1 and 85.9 responses/min during baseline and test sessions, respectively. In contrast, mean rates during sessions when there were changes in illumination were 45.4 and 40.0 responses/min during baseline and test sessions, respectively.

DISCUSSION

The present results indicate that illumination per se interpolated during the delay interval of a DMTS task does not produce retroactive interference. Rather, a change in delay-interval illumination conditions from those conditions that prevailed during training

Table 3

Mean keypecks/minute during delay intervals of each experimental condition.

Baseline: *Test:*	*ITI-DI* *on-on* *on-off*	*ITI-DI* *on-off* *on-on*	*ITI-DI* *off-off* *off-on*	*ITI-DI* *off-on* *off-off*
5-Day Baselines	202.7	43.4	147.0	39.7
Test Sessions	21.2	94.8	58.9	77.0
Baseline Recoveries	186.1	59.7	148.6	38.7

Note. The houselight conditions during the sample and comparison stimuli were identical to the houselight conditions during the ITI for each condition. DI = delay interval.

appears to be the more important variable. In the present experiment, either illuminated delays or dark delays resulted in reduced matching accuracy if the baseline delay intervals were, respectively, either dark or illuminated. Changing the delay-interval illumination conditions interfered with delayed matching whether there were changes in illumination during the test session (illuminated ITI and dark delay; dark ITI and illuminated delay) or were no changes in illumination during the test session (illuminated ITI and delay; dark ITI and delay).

These results run contrary to the commonly accepted conclusion that increases in delay-interval illumination result in retroactive interference and poor matching-to-sample performance (D'Amato, 1973; Roberts & Grant, 1976, 1978). The present results do not indicate that this conclusion is wrong; rather, the data in this experiment indicate that this conclusion is incomplete. Past research has not considered baseline illumination condition an important variable. A careful perusal of the experimental literature in this area showed that in all cases the training or baseline condition involved relatively dark delays and the manipulation was an increase in delay-interval illumination. The present experiment replicated the two experimental conditions that involved increases in delay-interval illumination and confirmed the conclusion that increases in delay-interval illumination, relative to the baseline condition, retroactively interfered with pigeon's delayed matching. The two experimental conditions that involved decreases in delay-interval illumination, relative to their baselines, are the novel conditions and the resulting disruption in delayed matching under these two conditions is the new finding. The results of the present research were anticipated by two earlier published reports (Herman, 1975; Zentall, 1973). Both of these studies suggested that novelty of interpolated stimulation is an important source of retroactive interference in animal short-term memory.

As pointed out by Roberts and Grant (1978), theories that attempt to explain the light-produced retroactive interference effect fall into two classes: Those based on memory loss and those based on some other processes. In a series of elegant experiments, Roberts and Grant have discredited most non-memorial based interpretations of the effect (Grant, 1975; Grant & Roberts, 1976, 1978) and offered as an alternative a memory-loss hypothesis. This memory-loss hypothesis states that "the degree to which memory is lost is a monotonically increasing function of the amount of light to which an animal is exposed regardless of whether amount of light is varied by changes in intensity or in length of exposure" (Grant & Roberts, 1978, p. 234). The implications of the present results concerning this hypothesis are clear: light per se during a delay interval did not interfere with delayed matching accuracy. Thus, it must be concluded that the present results disconfirm Roberts and Grant's memory-loss hypothesis as specifically stated.

A memory-loss hypothesis may still account, however, both for previous findings and the present results. A modified memory-loss hypothesis would simply state that the degree to which memory is lost is a monotonically increasing function of the amount of change in delay-interval illumination conditions relative to the baseline condition whether that change involves an increase or a decrease in delay-interval illumination.

A memory-loss hypothesis which posits change in illumination conditions as the important variable has the advantage of specifying a mechanism responsible for this memory loss. As has been proposed by others, memory for a sample stimulus may be maintained in short-term memory throughout the delay interval via a rehearsal process (Grant & Roberts, 1976). Introducing an unexpected change in illumination conditions may disrupt this rehearsal process and lead to loss of memory for the sample stimulus. As was suggested by others (Grant & Roberts, 1976; Roberts & Grant, 1978), a recent formulation of animal short-term memory by Wagner and his colleagues (Terry & Wagner, 1976; Wagner, 1976; Wagner, Rudy, & Whitlow, 1973) may account for the delay-interval change in illumination effect. The feature of Wagner's model that has particular importance to the present analysis is his prediction that certain events will undergo differential rehearsal. According to Wagner (1976, 1978), unexpected or surprising events will be postperceptually processed more than will expected events. Thus, in a DMTS task, when delay-interval illumination conditions are abruptly changed, the surprising nature of this event engages the rehearsal mechanism, takes up space in a limited capacity short-term memory, and prevents adequate rehearsal of the to-be-remembered sample stimulus. Consequently, delayed matching performance breaks down.

Although the present data are consistent with Wagner's analysis of memory for "expected" vs. "surprising" events, such an analysis may only superficially account for change-in-illumination retroactive interference effects. A "surprise" account of retroactive interference produced by unexpected illumination predicts that the novelty of the unexpected illumination would habituate with extended testing and the amount of interference would decrease. Although there are reports of retroactive interference decreasing as a function of increased testing when either keylight illumination (e.g., Zentall, 1973) or a brief auditory stimulus (e.g., Herman, 1975, Experiment II) is used as the source of interference, the more general finding when the interfering stimulus is nonlocalized and/or occurs throughout the delay is a sustained interference effect. For example, Shimp and Moffitt (1977, Experiment II) reported substantial retroactive interference even after 70 sessions of testing. In the present experiment, there was little evidence for reduced interference as testing continued. Only one bird, P309 in test condition *off-off*, showed substantial improvement over the three test sessions. In addition, birds that served in more than one houselight condition always required considerable retraining on their new baseline—at least 30 sessions—before they were ready for a new sequence of testing. It may be, therefore, that a "surprise" analysis of light-induced retroactive interference effects is untenable.

Furthermore, there may be conceptual problems in assuming that a change in illumination, essentially a contextual event, is surprising in the theoretical sense implied by Wagner's (1976, 1978) model. In the acquisition of eyelid conditioning in experiments conducted in Wagner's laboratory as well as a DMTS study by Maki (1979b) surprise was always defined as the unexpected occurrence or omission of an unconditional stimulus, e.g., shock or food. It may be that information concerning unconditional stimuli is processed by animals very differently than is information concerning contextual stimuli, e.g., a houselight. A recent experiment by Maki (1979a) may be interpreted as supporting the notion that unexpected illumination does not have the same effects on the acquisition of a task as does an unexpected unconditional stimulus. Maki (1979a) showed that unexpected illumination did not affect acquisition of an instrumental discrimination but did reduce accuracy of delayed matching to chance. These data seem to suggest caution in defining any unexpected change as "surprising" in the sense presumed by Wagner's (1976, 1978) model.

The nature of the present findings suggests several additional explanations that may account for the change-in-delay-interval-illumination retroactive interference effect. Generalization decrement (Denny, 1967, 1971) may adequately explain the present results as well as previous light-induced retroactive interference effects. If one assumes a DMTS task is learned via a backchaining process (Denny, 1967) or through the development of sample-specific mediating behaviors (Zentall, Hogan, Howard, & Moore, 1978), it must be assumed that chains of behavior are directly tied to the stimulus conditions present during the delay interval. When these delay-interval stimulus conditions are suddenly changed by turning the houselight either on or off, these behavior chains may be disrupted and delayed matching performance may consequently suffer.

Spear's (1978) retrieval deficit hypothesis is an alternative interpretation of the houselight interference effect. According to Spear, forgetting occurs when the stimulus events during testing fail to match attributes of the critical memory acquired during training. Acquisition of competing memories is considered a special case of retrieval failure. According to Spear, contextual stimuli may be important elements of acquired memories. Even minor changes in contextual stimuli between training and testing, therefore, may result in failure to retrieve the critical memory either directly or through the retrieval of competing memories that conflict with the to-be-remembered item. These notions translate easily to houselight interference in DMTS. It must simply be assumed that illumination conditions are contextual stimuli that are stored as critical elements of the delayed matching trial memory. When illumination conditions are abruptly changed, retrieval of the sample fails either because of insufficient retrieval cues or due to the retrieval of conflicting memories brought on by the illumination change.

One final aspect of the present data which suggests a different interpretation of the interference data is the differential rate of keypecking obtained during delay intervals dependent on whether there was or was not a change in illumination during the matching trial. High rates of responding were found when the houselight either remained on or remained off during the delay whereas low rates of keypecking occurred when the houselight was either turned on or turned off during the delay. It may be that a delay-interval change in illumination during baseline conditions *on-off* and *off-on* served as a discriminative stimulus or an instruction to remember the sample stimulus (cf. Maki, 1979b; Maki & Anundson, Note 1). When this cue was removed during test sessions (test conditions *on-on* and *off-off*) birds may have been unable to discriminate the delay interval from the ITI. Thus, birds no longer knew when to remember (i.e., during the delay) vs. when to forget (i.e., during the ITI). Consequently, matching performance suffered. In baseline conditions when a delay-interval change in illumination did not occur (conditions *on-on* and *off-off*), absence of an externally provided remember cue during the delay may have prompted birds to use their own behavior, a high rate of key pecking, as an instruction to remember (cf. Honig, 1978). When illumination conditions were subsequently changed during testing, this well-learned behavioral instruction was no longer necessary for birds to discriminate the delay from the ITI. Forgetting still occurred during testing, however, perhaps because insufficient exposure to the testing conditions did not allow the change in illumination during the delay to gain stimulus control of remembering.

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