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EFFECT OF DELAY-INTERVAL STIMULI ON DELAYED SYMBOLIC MATCHING TO SAMPLE IN THE PIGEON

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In Experiment 1, food-deprived pigeons received delayed symbolic matching to sample training in a darkened Skinner box. Trials began with the illumination of the grain feeder lamp (no food sample), or illumination of this lamp, accompanied by the raising of the feeder tray (food sample). After a delay of a few seconds, the two side response keys were illuminated, one with red and one with green light, with positions counterbalanced over trials. Pecking the red (green) comparison produced grain reinforcement if the trial had started with food (no food); pecking red after a no-food sample or green after a food sample was not reinforced. Once matching performance was stable, four stimuli were presented during the delay interval, and their effects on matching accuracy were evaluated. Both illumination of the houselight and the center key with white geometric forms decreased matching accuracy, whereas presentation of a tone and vibration of the test chamber did not. In Experiment 2, pecking the red center key was reinforced with food according to a variable interval schedule. The effects of occasional brief presentations of the four stimuli used in the first experiment on ongoing pecking were assessed. The houselight and form disturbed key pecking, but the tone and vibration did not. Thus, stimuli that interfered with delayed matching also interfered with simple operant behavior. Implications of these results for theories of remembering are discussed.

Key words: delayed symbolic matching to sample, delay-interval stimulation, interference, remembering, stimulus control, key peck, pigeons

Under delayed matching-to-sample (DMTS) procedures arranged for food-deprived pigeons, trials begin with the presentation of a sample stimulus such as red or green illumination of a pecking key, normally the center key of a horizontal array of three keys. A peck on the sample key turns off the sample and initiates a delay interval during which all three keys are dark. After the delay interval, two comparison stimuli, one of which is identical to the preceding sample, are presented on the side keys. Pecking the comparison that matches the preceding sample produces a grain reinforcer, followed by the intertrial interval. Pecking the nonmatching stimulus leads only to the intertrial interval. Generally, the stimuli occur as samples equally often, and the right-left location of the matching comparison is counterbalanced.

The delayed symbolic matching-to-sample (DSMTS) procedure is identical to the DMTS procedure except that neither comparison matches the preceding sample. Reinforcement for pecking a particular comparison depends on an arbitrary, experimenter-specified relation between sample and comparison stimuli. In some DSMTS experiments, different colored lights and forms have been used as sample and comparison stimuli (Brodigan & Peterson, 1976; D'Amato & Worsham, 1974). In others, the occurrence and nonoccurrence of an opportunity to eat have been used as samples and different colored lights as comparisons (Maki, Moe, & Bierley, 1977; Wilkie, 1978). In yet others, different patterns of behavior have served as samples and different colored lights as comparisons (e.g., Maki et al., 1977).

Variation in incidental stimuli during the delay interval often has a potent effect on matching accuracy in both DMTS and DSMTS. Except when sample and interpolated stimuli are highly similar (Medin, Reynolds, & Parkinson, 1980) the effect is generally a reduction in accuracy. Herman (1975) found that dolphins' performance on DMTS with auditory stimuli was disrupted when other auditory stimuli were presented during the

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delay interval. Illumination of a houselight during the delay interval during sessions in which the test chamber is otherwise darkened adversely affects both DMTS and DSMTS accuracy in both pigeon and monkey subjects (e.g., D'Amato & O'Neill, 1971; Grant & Roberts, 1976; Maki et al., 1977). Darkening the chamber during the delay in sessions conducted in an illuminated chamber disrupts pigeons' DMTS (Tranberg & Rilling, 1980). Illumination of a response key with colored light, dots in the form of a cross, or dots in the form of a diagonal also disrupts pigeons' DMTS (Grant & Roberts, 1976). Thus, the deleterious effects of delay-interval stimulation appear to be quite general.

EXPERIMENT 1

EFFECT OF DELAY INTERVAL STIMULI ON DSMTS

This experiment was a further investigation of the effects of interpolated delay interval stimuli on pigeons' DSMTS accuracy. In addition to replicating the effects of delay interval houselight illumination on DSMTS arranged in a darkened chamber, we studied the effect of an auditory stimulus, a vibratory stimulus, and illumination of a response key.

METHOD

Subjects

Three King pigeons were maintained at about 85% of their free-feeding weights by mixed grain obtained during experimental sessions and postsession supplemental feeding of maple peas. Water and grit were constantly available in the home cage. Each bird had been trained previously on DSMTS procedures similar to those employed here. None of the birds, however, had been exposed to interpolation of stimuli in the delay interval, and none had been exposed to the particular interpolated stimuli employed in the present study.

Apparatus

The light-proof, sound-attenuating BRS/LVE #132-02 test chamber contained a ventilation fan; a houselight (34 candela/m^2); a horizontal array of three BRS/LVE #121-16 clear plastic pecking keys, each equipped with a microswitch to sense pecks of about .2 N or greater and each mounted in front of an Industrial Electronics Engineers' Model 10-0229 projector containing a BRS/LVE slide #696 (triangle and square—2.5 candela/m^2; red and green—3.5 candela/m^2); a Sonalert SC628 (2900 Hz, 88 db) sound source; and a BRS/LVE #114-10 grain feeder, containing a lamp (30 candela/m^2). The houselight was mounted above, and the grain feeder below, the center key. The Sonalert was mounted to the right of the feeder. The vibratory stimulus was generated by a variable speed Bodine Electronic Co. Type NSE-11 120 V ac motor mounted on a 22.5 cm stand on the top of the test chamber. A 22 cm by 14.5 cm piece of cardboard was attached to the shaft of the motor so that the shaft was 3.5 cm from one end of the cardboard and 18.5 cm from the other. The motor rotated the cardboard eccentric about 500 revolutions per min.

Programming and data collection were performed by standard solid state and electromechanical circuits.

Procedure

As each bird had received previous DSMTS training, no preliminary training was necessary.

Baseline sessions. Daily sessions conducted in a darkened test chamber consisted of 40 trials spaced 30 sec apart—20 food as sample (F) trials and 20 no-food as sample ($\bar{F}$) trials, arranged in a semirandom order, the restriction being that each trial type had to occur equally often in each session. All trials began with 4-sec illumination of the feeder lamp. On F trials, the tray was raised so that the bird could eat mixed grain for 4 sec; on $\bar{F}$ trials, the tray remained lowered and inaccessible to the pigeon.

A delay interval began as soon as the feeder lamp was turned off. After the delay interval (8 sec for Bird 1, 3 sec for Bird 2, and 4 sec for Bird 3), the two side keys were illuminated—one with red and one with green light. The right-left location of red and green was counterbalanced over trials. A single peck on either side key turned off both keys and produced a 4-sec grain reinforcement period if the correct side key was pecked: red if the trial had started with an F sample, green if the trial had started with an $\bar{F}$ sample. Incorrect choices produced only the intertrial interval.

In each session, the number of trials on which the red and green comparison keys were pecked after F and $\bar{F}$ samples was recorded and used to calculate percent correct (percent of trials on which the correct comparison was chosen).

Test sessions. Test sessions began when matching appeared asymptotic and stable. These sessions were identical to Baseline sessions except that one of four interpolated stimuli was presented for the full duration of each of the delay intervals. A minimum of five baseline sessions separated Test sessions. Each of four types of delay interval stimuli (houselight, tone, vibration, and illumination of the center response key by a white geometric form) was presented during four consecutive Test sessions. The center response key was illuminated by a white triangle during two Tests and by a white square in two other Tests. The order in which the delay interval stimuli were presented was: houselight, tone, vibration, and forms.

RESULTS

Figure 1 shows percent correct matching for each bird during the five Baseline sessions preceding each Test session as well as percent correct during each Test. When the houselight or form stimuli were presented during the delay, matching accuracy was impaired, frequently to near chance levels. On the other hand, presentation of the tone or vibratory stimulus during the delay interval had no apparent effect on matching accuracy. These observations were confirmed by repeated measures analyses of variance performed on the data shown in Figure 1. For the Light data there was a Trials effect [F(5,10) = 168.35, $p < .001$], but no Replication effect [F(3,6) = 1.53] or Trials by Replication interaction [F(15,30) = .83]. A post-hoc Duncan's Multiple Range Test performed on the Trials factor at alpha of .05 revealed that the Test sessions differed from all of the Baseline sessions.

The results of the analysis on the Form data were similar. There was a Trials effect [F(5,10) = 7.12, $p < .01$], but no Replication effect [F (3,6) = .65] or interaction effect [F(15,30) = .66]. A Duncan's Multiple Range Test performed on the Trials factor at alpha of .05 revealed that the Test sessions differed from all of the Baseline sessions.

Similar analyses on the Tone and Vibration data revealed no Trials effects [Tone – F(5,10) = 2.25; Vibration – F(5,10) = .74].

Table 1 shows matching accuracy on F and $\bar{F}$ trials over all 20 Baseline and four Test sessions of light, tone, vibration, and form. As in a previous study (Wilkie, 1978) of DSMTS with F and $\bar{F}$ as samples, there was no consistent difference in percent correct matching on F and $\bar{F}$ trials. It is also apparent from Table 1 that delay interval stimulation had no consistent differential effects on F and F trials.

DISCUSSION

Our finding that houselight interferes with accurate matching on DSMTS replicates results reported by Maki et al. (1977). Our results as well show that key illumination interferes with DSMTS as it does with DMTS (cf. Grant & Roberts, 1976). We also found that tone and vibration do not affect DSMTS accuracy.

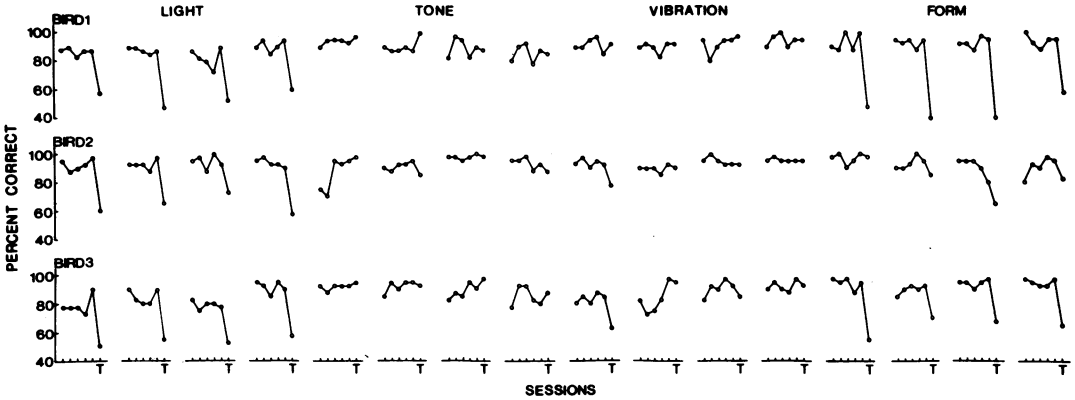

Fig. 1. The top, middle, and bottom panels show for Birds 1, 2, and 3 respectively, percent correct matching on the DSMTS procedure during the five Baseline sessions preceding each Test session (T) for the four replications of the four conditions—houselight (Light), Tone, Vibration, or white form on center key (Form) in the delay interval between sample and comparison stimuli.

Table 1

Matching Accuracy for F and $\overline{F}$ Samples

	Bird	*1*		*2*		*3*	
Condition	*Sample*	*F*	*$\overline{F}$*	*F*	*$\overline{F}$*	*F*	*$\overline{F}$*
Light Baseline		88.7	81.0	84.0	83.0	94.5	92.0
Light Test		53.8	55.0	63.8	47.5	72.5	55.0
Tone Baseline		88.3	90.3	89.5	88.8	95.0	89.0
Tone Test		92.5	92.5	88.8	97.5	92.5	91.3
Vibration Baseline		91.8	90.5	94.0	93.8	85.5	88.8
Vibration Test		97.5	91.3	87.5	90.0	85.0	82.5
Form Baseline		94.5	92.0	92.8	94.3	91.5	94.3
Form Test		61.3	31.3	47.5	81.3	80.0	85.0

While Herman (1975) found that dolphins' DMTS performance was disrupted by a delay interval tone, Worsham and D'Amato (1973) found no disruption of monkey's DMTS performance when white noise or recorded monkey vocalizations were presented during the delay interval. A possible reason for the different effects of delay interval auditory stimuli on matching accuracy in Herman's and in Worsham and D'Amato's studies may be that stimuli that interfere with matching are those that are in the same modality as the stimuli used in the matching task. Herman used auditory stimuli while D'Amato and Worsham used visual stimuli (geometric forms similar to those we employed) in the DMTS task. In the present study, the tone and vibration may have been ineffective because they were from different modalities than the samples (food and light, or light only) and the light comparisons.

EXPERIMENT 2

EFFECT OF EXTRANEOUS STIMULI ON RESPONDING MAINTAINED BY A VARIABLE INTERVAL FOOD REINFORCEMENT SCHEDULE

It is common practice in studies of conditioning to isolate subjects from sources of extraneous stimulation. The obvious rationale for this procedure is that such extraneous stimulation will disturb conditioned responding such as pigeons' key pecking. However, to our knowledge there are no empirical studies of such effects. Further, it is not known if stimuli that disturb responding in one context will have the same effect in another situation. Consequently, the present study was undertaken to determine if the four stimuli employed in Experiment 1 would disturb pigeons' key pecking maintained by a variable interval schedule of food reinforcement.

METHOD

Subjects

The three birds (numbered 1, 2, and 3) used in Experiment 1 also served in this study. Three naive King pigeons (numbered 4, 5, and 6) were also used. The birds were treated and housed as in Experiment 1.

Apparatus

The same apparatus as used in Experiment 1 was employed.

Procedure

Preliminary training. In this and subsequent phases the test chamber was normally dark except for feeder and key lamps. Birds 4, 5, and 6 were trained first to eat from the grain feeder. They were then trained, using the method of reinforcement of successive approximations, to peck the center key, which was illuminated with red light. These birds, as well as Birds 1, 2, and 3 were then exposed to a variable-interval food-reinforcement schedule. Food reinforcement consisted of 4-sec access to mixed grain and was available once every 60 sec on average (interreinforcement times ranged from 5 to 125 sec). Once pecking rates appeared asymptotic and stable, the experiment proper began.

Test phase. The experiment consisted of Baseline sessions, in which no stimulus was presented, and Test sessions in which seven 10-sec presentations of either the houselight, tone, white geometric form (triangle or square), or vibration occurred. During Test sessions a stimulus was presented according to a 5-min schedule (interpresentation values: 2, 4, 5, 6, and 8 min) that ran independently of the variable-interval food-reinforcement schedule. Each Test session was preceded and followed by a Baseline session.

Each stimulus was presented four times, the order of presentation being randomized with the restriction that the same stimulus not occur during two successive Test sessions.

During Test sessions frequency of pecking was recorded during the 10-sec period prior to each of the seven stimulus presentations. Pecking also was recorded during each of the presentations.

During Baseline sessions pecking was recorded during the 10-sec period when the stimulus would have occurred had it been a Test session. Pecking was recorded also during the 10-sec period prior to this period.

Sessions were approximately 35-min in duration, and were conducted daily.

RESULTS

For each Baseline and Test session a suppression ratio was calculated. In Test sessions these ratios were found by dividing rate of pecking during the 10-sec stimulus presentation by the sum of this rate and the rate during the preceding 10-sec period. [If rate of pecking was unaffected by the stimulus presentation, this ratio would be .5; if the presentation disturbed pecking, the ratio would be less than .5. Actual response rates (pecks/sec) during the prestimulus period for each Test are shown in Table 2.] A similar ratio was calculated for Baseline sessions. Figure 2 shows these suppression ratios for the Baseline session before and after each Test session as well as those for each Test session, for each replication for each stimulus (Light, Tone, Vibration, and Form). Due to illness, Bird 1 received only 2 replications. The houselight and form stimuli disturbed the pigeons' pecking for food reinforcers. Except for one occasion out of 44 tests, Light and Form produced large decreases in rate of key pecking. On the other hand, Tone and Vibration decreased responding in only five of 44 tests.

These observations were confirmed by a repeated measures analysis of variance performed on the suppression ratios averaged over replications. There was a sessions effect for Light [$F(2,10) = 461.2$, $p < .001$] and Form [$F(2,10) = 61.67$, $p < .001$], but not for Tone [$F(2,10) = 1.41$] or Vibration [$F(2,10) = 2.92$]. A post-hoc Duncan's test performed on the session data for Light and Form at alpha of .05 revealed in both cases that the Test suppression ratio differed from both Baseline ratios and that the Baseline ratios did not differ from each other.

Figure 3 shows a scattergram plot of Birds 1, 2, and 3's average decrease in matching when Light, Tone, Vibration, or Form was presented during the delay in Experiment 1 versus average change in suppression ratio from Baseline to Test for these same stimuli superimposed on food-reinforced responding in Experiment 2. (The latter measure was found by subtracting the Test suppression ra-

Table 2

Response Rates (Pecks/Sec) During Prestimulus Period for Test Sessions

		Bird					
Replication	***Stimulus***	*1*	*2*	*3*	*4*	*5*	*6*
1	Light	.30	1.37	2.13	1.20	.59	.79
2		.30	1.60	1.60	1.05	.59	.84
3		–	1.61	1.28	.95	.08	.32
4		–	1.44	1.30	.86	.22	.49
1	Tone	.26	1.06	1.01	.88	.41	.80
2		.27	1.53	1.47	1.10	.56	.66
3		–	1.33	1.43	1.34	.03	.44
4		–	1.83	1.43	.65	1.15	.51
1	Vibration	.32	1.03	1.29	1.10	.41	.81
2		.15	1.01	.86	1.35	.44	.84
3		–	1.90	1.67	.90	.51	.66
4		–	2.46	1.58	.98	.23	.39
1	Form	.30	.94	.20	.89	.58	.80
2		.70	1.61	1.98	1.10	.78	.91
3		–	1.52	.89	1.38	.07	.63
4		–	1.38	1.49	1.09	.60	.71

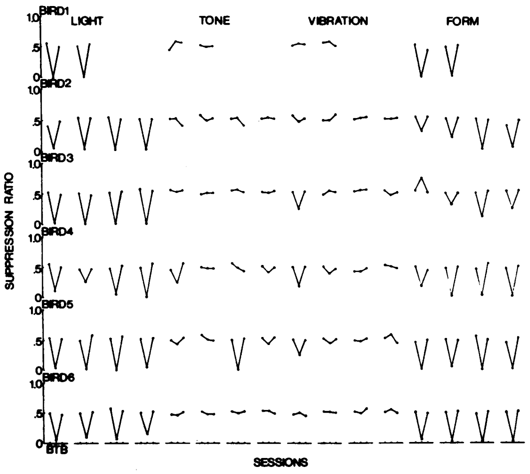

Fig. 2. The panels, from top to bottom, show for Birds 1 to 6 respectively, suppression ratios during triplets of Baseline (B), Test (T), then Baseline sessions for the four replications (two for Bird 1, due to illness) of the four conditions—houselight (Light), Tone, Vibration, and white form on center key (Form). Suppression ratios were found by dividing rate of pecking the red key during the 10-sec test period by the sum of this rate and the rate during the 10-sec period preceding the test period.

tio from the average Baseline suppression ratio. Consequently, *larger* values represent more suppression.) There is a clear correlation between interference with DSMTS and disturbance of food-reinforced key pecking.

Discussion

Pigeons' ongoing food-reinforced key pecking was disturbed by the houselight and white geometric forms on the red pecking key, whereas presentation of a tone or vibration of the test chamber produced little consistent change in rate of pecking. Thus, the same types of stimulation that disrupted DSMTS in Experiment 1 disturbed ongoing food reinforced behavior here; conversely, stimulation that did not disrupt DSMTS did not disrupt ongoing pecking. This correlation will be discussed in more detail in the General Discussion below.

EXPERIMENT 3
DISCRIMINATION OF NONINTERFERING STIMULI

There are several reasons why a stimulus such as tone or vibration may not interfere with learned behavior. One of the simplest reasons, the one to which the present study was addressed, is that the subject simply may be incapable of detecting such stimulation. We used a successive discrimination procedure to assess this possibility. The parameters of this procedure, while probably not optimal, were chosen so as to keep stimulus presentations relatively brief, as in the earlier experiments.

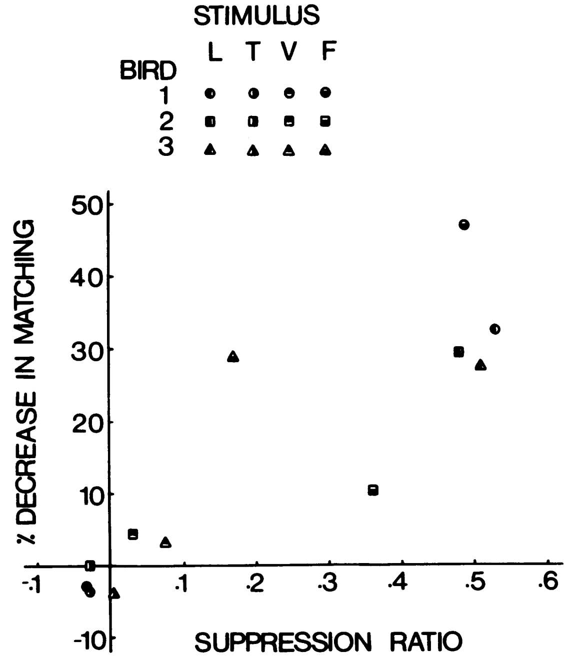

Fig. 3. Scattergram plot of Birds 1, 2, and 3's average decrease from Baseline in matching performance when Light, Tone, Vibration, and Form were presented during the delay interval in Experiment 1 versus average change in suppression ratio from Baseline to Test when the same stimuli were superimposed on food reinforced responding in Experiment 2.

Method

Subjects

The same subjects that had served in Experiment 2, except Bird 1, were used.

Apparatus

Same as in Experiments 1 and 2, except that no houselight was used.

Procedure

A white geometric form (triangle for Birds 3 and 5; square for Birds 2, 4, and 6) was projected on the red center key for 10 sec every 5 min on average (interpresentation values were 2, 4, 5, 6, and 8 min). The first peck 5 sec after the offset of the form produced a 4-sec grain reinforcer as did the first peck 10 sec after the offset of the form. Reinforcement was unavailable at all other times, including the 10-sec stimulus presentation period.

Rates of pecking were recorded during the 10-sec stimulus presentation (S+) and during the 10 sec preceding the presentation (S−).

After several sessions the form was replaced by the tone (Birds 3 and 5) or the vibratory stimulus (Birds 2, 4, and 6). During the final phase, the tone and vibration stimuli were interchanged.

Results

Rate of pecking (pecks/sec) during the 10-sec presentation (S+) of the form, tone, and vibration stimuli and during the 10-sec period preceding presentation of the stimuli (S−) are shown for each bird in Figure 4. The differential rates of pecking in S+ and S− when Tone and Vibration predicted food availability show that the birds were capable of detecting the stimuli.

A repeated measures analysis of variance was performed on pecking rates (averaged over the last 5 days of a condition) during presence and absence of each of the stimuli. Rates during S+ were higher than during S− for Form [F(1,4) = 36.48, $p < .01$], Tone [F(1,4) = 12.42, $p < .05$], and Vibration (F(1,4) = 85.86, $p < .01$].

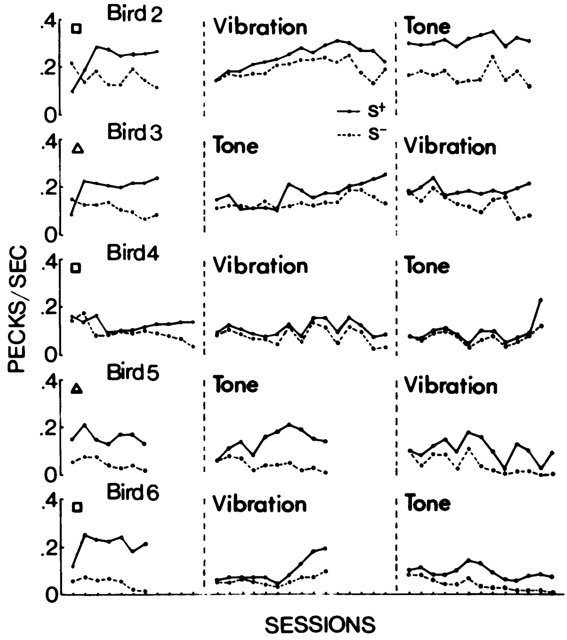

Fig. 4. The panels, from top to bottom, show for Bird 2 to 6 respectively, rates of pecking during the stimulus (Form, Tone, or Vibration) associated with reinforcement availability (S+) and during their absence (S−).

Discussion

Pigeons are capable of detecting the stimuli that failed to disrupt their performance on the DSMTS task or disturb their ongoing food reinforced key pecking. While this finding, of course, does not prove that the birds actually did detect these stimuli in the earlier experiments, it is consistent with the results reported by Worsham and D'Amato (1973). In their study, while delay interval monkey vocalizations did not disrupt DMTS performance, vocalizations presented together with a houselight produced less disruption than the houselight alone. Consequently, their monkeys clearly seemed capable of detecting the ineffective vocalizations.

GENERAL DISCUSSION

In order to perform accurately on delayed matching tasks a subject must remember for a period of time which stimulus served as the sample on that trial. When a treatment adversely affects matching accuracy, it seems common practice to attribute the decreased accuracy to an adverse effect of the treatment on the act of remembering the sample. Yet some treatments [e.g., delay of reinforcement for choice of correct comparison—cf. Wilkie & Spetch, (1978)] affect matching accuracy when it is unlikely for the treatment to have influenced remembering. Accordingly, one must be cautious in attributing the deleterious effects of treatments to interference with remembering.

While interpolated delay-interval stimuli may interfere with delayed matching performance by disrupting the act of remembering the sample, it seems possible as well that the interpolated stimuli could have disrupted the act of pecking the comparison, with or without disturbing remembering of the sample. The latter possibility is bolstered by the present finding that the same stimuli that disrupt reinforced key pecking also disrupted delayed-matching performance.

It seems clear that no precise resolution between these kinds of possibilities can be made now. However, future research may be able to distinguish between interference produced via effects on remembering the sample and via disruptive effects on reinforced key pecking. One kind of finding that would favor an interference-with-remembering account would be the discovery of stimuli that interfere with delayed matching performance but do not disturb reinforced key pecking.

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