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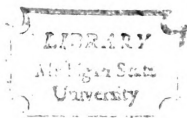
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TRACE SUPRAORDINATE STIMULUS CONTROL
OF DELAYED MATCHING-TO-SAMPLE
PERFORMANCE

By

Donald F. Kendrick, Jr.

A THESIS

Submitted to

Michigan State University

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ABSTRACT

TRACE SUPRAORDINATE STIMULUS CONTROL OF DELAYED MATCHING-TO-SAMPLE PERFORMANCE

By

Donald F. Kendrick, Jr.

Pigeons were studied in a delayed matching-to-sample (DMTS) procedure with trace supraordinate stimulus interpolated into the delay intervals to signal the occurrence or nonoccurrence of delayed stimulus events. In all three experiments one supraordinate stimulus, a C-cue, signalled presentation of the comparison stimuli and another supraordinate stimulus signalled the absence of the comparison stimuli. Control of DMTS performance by this stimulus was assessed in a probe procedure. On infrequent probe trials the comparison stimuli were presented at the end of the delay interval, contrary to training. Accurate choice responding may be considered remembering and inaccurate responding may be considered forgetting. The results demonstrated that when contingencies required similar behavioral output correlated with both supraordinate stimuli matching performance was accurate, indicating remembering. When contingencies required different behavioral output correlated with each supraordinate stimulus matching performance was inaccurate, indicating forgetting. These experiments serve to establish an empirical analysis of DMTS performance and offer a context-dependent retrieval theory of short-term remembering behavior.

To the children, Chloe (age 9) and Zak (age 7) who patiently (and sometimes not so patiently) attended my long-winded discourses on this research--not a word of which they understood. And to Emily (age 4) whose childish wonderment of writing, typing, and editing provided a source of amusement and was the primary motivation for the finishing and binding of this thesis.

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INTRODUCTION

Recently attention has turned to delayed matching-to-sample (DMTS) as a procedure for investigating animal short-term memory (D'Amato, 1973; Grant and Roberts, 1976; Maki, 1979; Medin, Reynolds, and Parkinson, 1980; Roberts and Grant, 1978; Shimp and Moffitt, 1974; Tranberg and Rilling, 1980; Zentall, Hogan, Howard and Moore, 1978). In the typical DMTS procedure a sample stimulus is presented for a fixed duration and, after a brief delay interval, comparison stimuli are presented. A response to the comparison stimulus that matches the previously presented sample stimulus is reinforced, while a response to the nonmatching comparison stimulus terminates that trial without reinforcement. Some researchers assume that a representation of the sample stimulus is maintained or rehearsed during the delay interval (e.g., Maki, 1979; Roberts and Grant, 1978). In contrast, Stubbs, Vautin, Reid and Delehanty (1978) offer a procedural definition of memory free of such theoretical encumbrances; "...memory refers to the control of behavior by prior stimuli" (p. 168). "Prior stimuli" are also termed trace stimuli. According to Stubbs', et al, definition, DMTS is a trace stimulus control procedure; the sample stimulus is a trace stimulus which is terminated prior to the occurrence of the behavior it controls (cf, Meehan, 1979; Wilkie and Wilson, 1977).

Maki and Anundson (1979) modified the typical DMTS procedure by including a post-sample stimulus that signalled the cancellation of the comparison stimuli on that trial. Once a steady baseline had been

achieved, they occasionally included "probe trials" in which the comparison stimuli were presented after the post-sample stimulus, contrary to training. On probe trials performance dropped to 75% correct responses compared to 93% on baseline trials. They assumed that the pigeons rehearsed the sample stimulus during the delay interval and that by "cuing" trials in which no comparison stimuli were presented rehearsal was discontinued. That is, they hypothesized that the cue gained stimulus control of rehearsal. They labeled this procedure "directed forgetting" to reflect the notion that the post-sample cue, a forget cue, terminates rehearsal and results in the apparent forgetting of the sample stimulus.

Stonebraker (1980) argued that the results of Maki and Anundson's (1979) experiment could be attributed to generalization decrement. Disruption of DMTS performance may have occurred because presentation of comparison stimuli on probe trials was inconsistent with previous training. In his Master's Thesis, Stonebraker positioned remember cues (R-cues), signalling the presentation of the comparison stimuli, and forget cues (F-cues), signalling the cancellation of the comparison stimuli, at three locations within the delay interval: immediately after the sample stimulus, in the middle of the delay, and at the end of the delay interval. His rationale was that presenting comparison stimuli after an F-cue in probe trials is equally novel regardless of the temporal positions of the cue. Therefore, if the lowered accuracy of DMTS performance on probe trials is due to generalization decrement, then all cue positions should equally disrupt performance. The rehearsal position assumes that the amount of disruption is dependent on the point of interpolation since the later the cue the more time to rehearse and the less time to forget. Stonebraker (1980) found that

matching performance was improved the later the forget cue; a result he interpreted as support for the rehearsal position.

Although rehearsal is an intriguing theoretical concept, Maki and Anundson's (1979) and Stonebraker's (1980) procedures may benefit from an empirical orientation which views their results as demonstrating trace supraordinate stimulus control of DMTS performance. A trace supraordinate stimulus (i.e., an instructional stimulus) is a stimulus that is presented and is terminated prior to the occurrence of the specific procedural variation that it is uniquely correlated with (Meehan, 1979; Reynolds, 1975). For example, an F-cue is a trace supraordinate stimulus informing the subject that the comparison stimuli are cancelled for that trial. Similarly, the R-cue is a trace supraordinate stimulus informing the subject that the comparison stimuli are to be presented at the end of the delay interval. In delayed matching-to-sample, trace supraordinate stimulus control is exhibited when matching performance is shown to differ following the occurrence of different trace supraordinate stimuli.

The advantages of this behavioristic approach are: integration of animal memory research with research on stimulus control, subjecting cognitive concepts to an experimental analysis, and extending the conditions within which trace supraordinate stimuli are manipulated. Using only two procedures, each associated with a unique trace supraordinate stimulus, dichotomous terminology such as remember and forget cues may serve well enough, but they are not easily extended to cover the full range and richness of the possible variations and combinations of conditional and unconditional discrimination procedures. Therefore, it is advisable to employ a term with broader scope, a term such as trace supraordinate stimuli, and to refer to these stimuli or cues in reference

to the procedures they are correlated with rather than their intended effects. For example, a trace supraordinate stimulus correlated with the occurrence of the comparison stimuli is a C-cue, rather than an R-cue, to reflect that it is correlated with the presentation of the Conditional discriminative stimuli, or Comparison stimuli. The trace supraordinate stimulus correlated with the nonoccurrence of the comparison stimuli is a NRFT-cue, rather than an F-cue, to reflect that it is correlated with NonReinForcement; cancellation of the comparison stimuli.

The data of Maki and Anundson (1979) and Stonebraker (1980) indicate stimulus control of matching performance by trace supraordinate stimuli. Their "directed forgetting" effect may simply be another example of stimulus control; specifically, trace supraordinate stimulus control. Therefore, elaborate theoretical constructions (e.g., rehearsal) may not be required to explain their finding. The objective of the following experiments was to determine to what extent factors influencing the development of stimulus control have similar influences in the development of trace supraordinate stimulus control of delayed matching-to-sample performance.

Nevin (1973) and Rilling (1977) define stimulus control in terms of the slope of stimulus generalization gradients. Differential reinforcement is a procedure that steepens the generalization gradients indicating enhanced stimulus control. Differential reinforcement has also been shown to enhance supraordinate stimulus control of DMTS performance. Mintz, Mourer and Weinberg (1966) used an array of lights as supraordinate stimuli. When the last lights of the array were illuminated reinforcement was available contingent upon a correct DMTS response. Correct responses on trials prior to the last one were not reinforced by food presentation, but sequentially illuminated another light in the

array. This procedure resulted in relatively more accurate matching toward the end of the sequence than at the beginning, i.e., accuracy increased as proximity to reinforcement increased. To determine whether the lights at the end of the array were controlling matching performance Mintz, et al, illuminated them out of sequence, at the beginning of probe trials, and found that matching performance improved over baseline. This result demonstrated that the light array exerted supraordinate stimulus control of DMTS performance. Nevin (1973) viewed this experiment as differential reinforcement of matching behavior, i.e., those DMTS responses early in the light array were not reinforced and the DMTS response occurring at the end of the light array sequence was reinforced. These data indicate that differential reinforcement is a factor in supraordinate stimulus control and suggest that differential reinforcement may also be a factor in trace supraordinate stimulus control.

Experiment 1 compares the effects of differential and nondifferential reinforcement correlated with trace supraordinate stimuli on matching performance in procedures similar to Maki and Anundson's (1979) and Stonebraker's (1980). Experiment 1 required a keypeck to obtain reinforcement after both trace supraordinate stimuli in the nondifferential reinforcement condition. Experiment 2 furthers the analysis of nondifferential reinforcement by employing a procedure in which response-independent reinforcement is correlated with one trace supraordinate stimulus and response-dependent reinforcement is correlated with the other trace supraordinate stimulus. Response-independent reinforcement weakens stimulus control (Nevin, 1973) and therefore may also weaken trace supraordinate stimulus control. The results of Experiment 2 suggested that delay interval behaviors may be an important factor in the development of trace supraordinate stimulus control of DMTS performance.

Conditions that produced similar delay interval behaviors also resulted in similar matching performance. Experiment 3 examined the role of differential delay interval behavior in a procedure in which different behaviors were required during the delay intervals, each correlated with a different trace supraordinate stimulus, and in which the same behaviors were required at the end of the delay intervals. It was shown that end-of-delay interval behaviors, rather than behaviors during the delay intervals are the critical factor in accurate matching performance. Table 1 presents the design, manipulations, and primary results of each of these experiments.

Table 1

Outline of Experimental Procedures and Primary Results

Experiment	Trace Supraordinate Stimulus	Procedure	Matching Performance
<u>1</u>	A C-cue	comparison stimuli presented	accurate
	UC-cue	unconditional discriminative stimuli presented	accurate
	B C-cue	comparison stimuli presented	accurate
	NRFT-cue	comparison stimuli cancelled	inaccurate
	A C-cue	comparison stimuli presented	accurate
	UC-cue	unconditional discriminative stimuli presented	accurate
<u>2</u>	A C-cue	comparison stimuli presented	accurate
	RI-cue	response-independent reinforcement	equivocal
	B C-cue	comparison stimuli presented	accurate
	K-cue	orient to keys or peck center key for reinforcement	accurate
	C C-cue	comparison stimuli presented	accurate
	M-cue	magazine approach response delivers reinforcement	inaccurate
<u>3</u>	A C-cue	comparison stimuli presented	accurate
	MUC-cue	magazine approach response initiates presentation of the unconditional dis- criminative stimuli	accurate

EXPERIMENT 1

Differential reinforcement of trace supraordinate stimuli is a characteristic of both Maki and Anundson's (1979) and Stonebraker's (1980) procedures. The negative trace supraordinate stimulus, a NRFT-cue, was correlated with the absence of the comparison stimuli and therefore with the absence of an opportunity for reinforcement. The conditional trace supraordinate stimulus, a C-cue, was correlated with the presence of the comparison stimuli and therefore correlated with an opportunity for reinforcement. The trace supraordinate stimulus control exhibited in their experiments may be due to differential reinforcement correlated with the C- and NRFT-cues.

Experiment 1 employed a trace supraordinate conditional discrimination procedure. On all trials one of two trace supraordinate stimuli was presented during the delay intervals immediately after the sample stimulus and was terminated prior to the end of the delay interval. In the first condition a trace supraordinate stimulus, a C-cue, was correlated with the presentation of the conditional discriminative stimuli, the comparison stimuli, and a second trace supraordinate stimulus, a UC-cue, was correlated with the presentation of the UnConditional discriminative stimuli. This condition represents nondifferential reinforcement correlated with trace supraordinate stimuli. In the second condition a trace supraordinate stimulus correlated with the absence of the comparison stimulus, a NRFT-cue, replaced the UC-cue of the first condition. C-cued trials continued as in the first condition. This

second condition is a modified replication of Maki and Anundson's (1979) procedure and reflects differential reinforcement correlated with the trace supraordinate stimuli.

This experiment pits the stimulus control interpretation against the rehearsal interpretation. According to the rehearsal interpretation the trace supraordinate stimulus that is correlated with the absence of the comparison stimuli, the NRFT-cue, terminates a rehearsal process. It seems plausible that rehearsal may also be terminated by a trace supraordinate stimulus correlated with the presentation of unconditional discriminative stimuli, the UC-cue, since memory of the sample stimulus is not required to gain reinforcement. Thus, a rehearsal position predicts inaccurate matching performance on probe trials in both the differential and nondifferential reinforcement conditions. According to the stimulus control interpretation nondifferential reinforcement correlated with the trace supraordinate stimuli weakens stimulus control and differential reinforcement strengthens stimulus control. Thus, a stimulus control position predicts accurate matching performance (weak stimulus control) on probe trials in the nondifferential reinforcement condition, C-and UC-cues, and reduced matching accuracy on probe trials (enhanced stimulus control) in the differential reinforcement condition, C-and NRFT-cues.

Method

Subjects

Four naive adult White Carneaux pigeons were maintained at $80\% \pm 20g$ of their free-feeding weights and were individually housed in a temperature controlled, constantly illuminated, colony room. Water and grit were always available.

Apparatus

A three-key Lehigh Valley Electronics pigeon chamber was used. The 2.54 cm diameter plastic keys required a force of 15 g (.15 N) for activation. The three keys were positioned 5.5 cm apart, were 9 cm from the top of the chamber, 8 cm from the sides and 25.5 cm from the floor. The houselight (28 V dc, GE 757) was above the center key, 2.5 cm from the top of the chamber. The grain magazine was 5 x 5 cm, 11.5 cm from the floor and positioned under the center key. The keys were illuminated by a display projector (IEE Series 10, 28 V dc, GE 747). The walls of the chamber were white matte with an unpainted aluminum stimulus panel. Masking noise was provided by a small ventilation fan. Electro-mechanical programming equipment controlled by a paper-tape reader was in an adjoining room.

Procedure

In all conditions reinforcement was 2.5 sec access to mixed grain. The maximum number of reinforcers attainable depended upon the stage of the experiments. After pretraining, the actual number of reinforcers delivered depended upon the birds' performance.

Pretraining. All birds were first magazine trained on a VT 45 sec schedule following Catania and Reynold's (1968) constant probability formula. When birds were approaching the magazine and eating reliably, autoshaping trials began. Autoshaping followed the VT 45 sec schedule used in magazine training with six seconds of red or green illumination on the center key. Red and green were presented randomly such that one color did not appear more than three times successively and each occurred an equal number of times within a session. Autoshaping continued in approximately one hour daily sessions until a minimum of 100 total responses were obtained in a single session.

Acquisition of Delayed Matching-to-sample. The basic procedure was two-choice delayed matching-to-sample with red and green key lights as sample and comparison stimuli. Following a 30 sec intertrial interval (ITI) red or green sample stimulus transilluminated the center key for 12 sec. A keypeck then terminated the sample stimulus and initiated a 1 sec supraordinate stimulus. A white 5 mm diameter circle on the center response key (C-cue) signalled the presentation of the comparison stimuli, and a white 3 mm equilateral triangle (UC-cue) signalled the presentation of the unconditional discriminative stimuli. Following the termination of the C-cue, both side keys were illuminated red and green and a single peck to the color that matched the sample resulted in reinforcement. A peck to the nonmatching color initiated the ITI. Following the termination of the UC-cue, one side key was illuminated by a white horizontal bar and the other side key by a white vertical bar, each 2 mm x 2.54 cm on a black surround. A peck to the vertical bar resulted in reinforcement. A peck to the horizontal bar initiated the ITI regardless of the color of the preceding sample stimulus.

Red and green sample stimuli were semi-randomly presented such that the same color did not appear more than three times in succession and each occurred an equal number of times per session. C-cues and UC-cues were equally likely after red and green sample stimuli, did not appear more than three times on successive trials, and occurred an equal number of times per session. Left and right side keys were red and green an equal number of times with no more than three trials of the same color on the same side in succession. The two side key combinations, red-left, green-right, and red-right, green-left, appeared an equal number of times per session.

The birds were exposed to all stimulus events and contingencies from the first session. There were 36 C-cued and 36 UC-cued trials per session. Each session lasted approximately one hour. Delay intervals were 1 sec, the same duration as the cues, and were incremented by 1 sec upon the completion of two sessions with 80% or more correct responses. All birds were thus advanced to and maintained at 4 sec delay intervals.

Baseline and Testing. Two baseline conditions were arranged in an ABA format. In the A condition, the equilateral triangle projected on the response key was a trace supraordinate stimulus signalling the presentation of the unconditional discriminative stimuli, UC-cue, the same as during acquisition. In the B condition, the equilateral triangle was a trace supraordinate stimulus signalling the end of that trial without keylight stimuli and without an opportunity for reinforcement, NRFT-cue. Each of the three stages of the experiment lasted approximately three to five months. Completion of condition A was required prior to condition B, completion of which was required prior to reinstating condition A. Twenty sessions of each condition were required prior to test sessions with the last five at or above 80% correct choice performance. The 80% criterion was based on percentage correct responses on the 36 C-cued trials. The minimum requirement was 29 correct responses out of 36 responses. Performance on the UC-cued trials was not considered.

Three blocks of test sessions, one during each of the three stages, were conducted. A test session contained four probe trials in which the comparison stimuli were presented instead of horizontal and vertical bar stimuli (condition A) or instead of the ITI (condition B). Probe trial stimulus events were controlled such that red and green sample

stimuli were equally likely to be followed by the two comparison stimuli combinations in each session. A response to the matching comparison stimulus produced reinforcement and an incorrect response ended the trial. Five test sessions were conducted for a total of 20 probe trials per stage. Baseline sessions alternated with test sessions as long as 80% or more correct choice responding was maintained. On test sessions, the baseline percentage criterion was lowered to 75% (27/36) to allow for possible local disruptive effects due to the incongruency of probe trial contingencies. The experiment ended upon completion of the fifth probe session of the last condition.

Results

Figure 1 shows percentage correct choice responses in baseline and probe test conditions for each of the four pigeons as a function of the cue contingency conditions. Table 2 shows the same data for each pigeon averaged over all sessions. In Figure 1, the solid circles represent the baseline data of 36 C-cued trials per session. Open circles represent the test data of four UC- and NRFT-cued probe trials per session. In the first A condition, the left panel, all birds maintained high percentages of correct choice responses. Performance on the 5-day baseline, test baseline and test probes were similar. The respective means are 88.5%, 87.6%, and 89.0% averaged over all birds. Nondifferential reinforcement associated with the trace supraordinate stimuli resulted in similar and accurate matching performance.

The middle panel of Figure 1 shows that the B condition effectively reduced matching accuracy on NRFT-cued trials. The NRFT-cued test probe mean for all birds dropped to 53.3%, near chance, and baseline

Figure 1. Matching performance as function of reinforcement conditions.

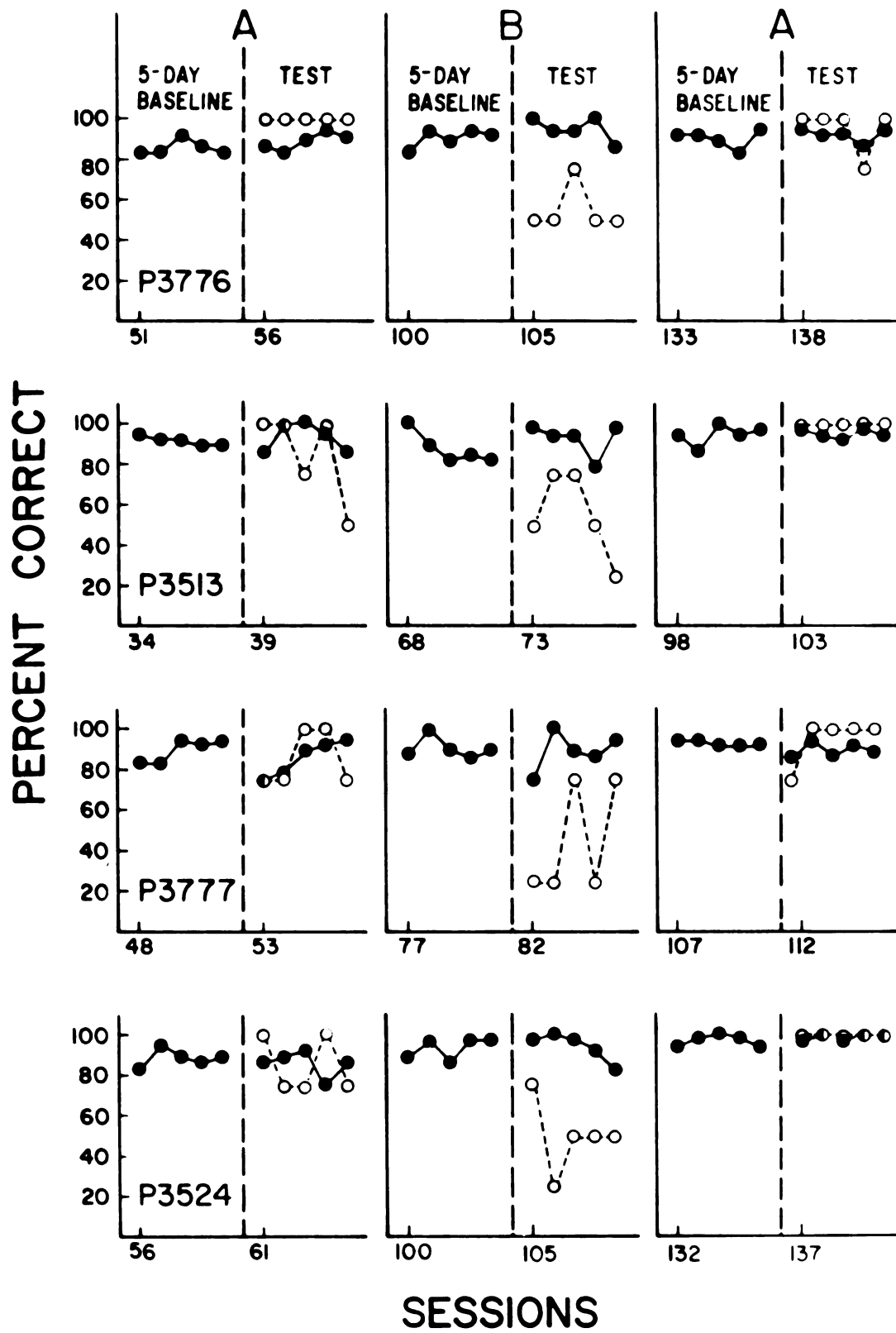


Table 2

Summary of data presented in Figure 1 showing the mean percentages correct and standard errors for each pigeon and each condition.

Condition	P3776			P3513			P3777			P3524		
	Mean % Correct	SE	Mean % Correct	SE	Mean % Correct	SE	Mean % Correct	SE	Mean % Correct	SE	Mean % Correct	SE
<u>A</u>	5-day Baseline Test	85.40	1.75	91.20	.97	89.20	2.56	88.20	1.83			
	Baseline Test	86.60	2.29	93.20	3.14	86.20	3.57	85.60	2.87			
	Probes	100.00	0.00	85.00	10.00	85.00	6.12	85.00	6.12			
<u>B</u>	5-day Baseline Test	90.40	2.06	93.40	1.83	88.20	1.83	93.20	2.37			
	Baseline Test	94.80	2.58	92.00	3.56	88.80	4.19	93.80	2.99			
	Probes	55.00	5.00	55.00	9.35	45.00	12.25	50.00	7.91			
<u>A</u>	5-day Baseline Test	90.00	1.92	94.20	2.33	91.00	0.51	96.40	0.89			
	Baseline Test	91.60	1.47	94.80	0.97	89.40	1.60	98.80	0.73			
	Probes	95.00	5.00	100.00	0.00	95.00	5.00	100.00	0.00			

means increased to 91.3%, for the 5-day baseline, and to 92.4% for the test baseline. When trace supraordinate stimuli were correlated with differential reinforcement they gained stimulus control of matching performance. The A condition was repeated and the data appear in the right panel of Figure 1. Again, baseline means of all birds are comparable, 92.9%, for the 5-day baseline, and 93.7% for the test baseline. On probe trials performance was somewhat better at 97.5% mean correct choice responses. The nondifferential reinforcement condition again demonstrated loss of stimulus control by trace supraordinate stimuli. In summary, comparing the means of the probe trials of the A conditions with that of the B condition, 89.0% and 97.5% vs 53.3%, it is clear that differential reinforcement effectively reduced matching performance to near chance and that the nondifferential reinforcement condition resulted in matching accuracies similar to baseline accuracies.

Position preferences were also noted in all four birds, 3776 and 3513 pecked the left key more than the right key and 3777 and 3524 pecked the right more. Table 3 presents side key position preferences and delay interval data for each pigeon across all conditions. Percentage correct choice responses were affected by the birds' side key preference as indicated by higher matching accuracy on the preferred key.

Table 3 also shows that delay interval keypecking was low with the NRFT-cue and at a higher rate with the UC-cue. In the B condition C-cued delays supported more responding than NRFT-cued delays, 142 mean responses vs 25 mean responses, respectively. In the A conditions responding was similar during C-cue and UC-cued delay intervals, 123

Table 3
Delay interval keypecking and choice responses for each condition

Condition	*	P3776		P3513		P3777		P3524	
		5-day		5-day		5-day		5-day	
		Base	Test	Base	Test	Base	Test	Base	Test
Delay	C	28	23	26	313	89	81	111	117
	UC	24	16	21	281	84	80	100	112
Choice	L	18	18	17	18	15	15	15	14
	R	14	16	13	16	16	17	17	15
Totals	L	157	181	182	86	41	37	39	35
	R	32	35	35	42	75	73	63	531
Delay	C	6	3	3	26	31	19	22	48
	NRFT	108	96	94	138	46	46	46	187
Choice	L	17	18	18	17	16	17	15	16
	R	15	16	15	16	16	17	17	18
Totals	L	92	102	84	36	18	24	23	16
	R	21	22	20	22	56	69	60	33
Delay	C	8	9	10	175	100	135	144	74
	UC	52	36	26	286	105	118	131	168
Choice	L	18	18	17	17	16	17	17	17
	R	15	17	15	18	17	18	17	18
Totals	L	252	163	196	56	34	38	39	34
	R	28	30	31	42	75	54	51	46

* C, C-cued trials; UC, UC-cued trials; L, Left key; R, Right key; NRFT, NRFT-cued trials.
Data are means based on 5 sessions; the Test Base Totals are from the sessions prior to the test sessions with probe trials.

mean responses vs 133 mean responses, respectively; in the first A condition; and 126 vs 103, respectively, in the second A condition. This difference is primarily due to one bird, 3776, who did not recover its former high rate of UC-cued delay responding during the second A condition. Informal observation indicated 3776 increased left key pecks during the delay intervals and the increase in total left key pecks provide support (see Table 3). Pigeon 3776 increased left key pecks from a mean of 173 to 204 from the first A condition to the second, while the other three birds decreased the rate of response to their biased key from the first condition to the last. Pigeon 3513 decreased from a mean of 73 pecks on the left key to 56, pigeon 3777 from a mean of 70 to 60 and pigeon 3524 from a mean of 432 to 52. In general then, in the NRFT-cued condition delay interval keypecking was reduced and in the UC-cued condition delay interval keypecking was maintained at a rate similar to that maintained during C-cued delay intervals.

Disruption of matching performance was noted in all birds when changed from condition A to condition B. The mean percent correct for the last five sessions of condition A was 87%, the mean correct for the first five sessions of condition B was 68%. These percentages are based on the C-cued trials only. When returned to condition A from condition B no disruption was evident. The mean for the last five sessions of condition B was 91% and for the first five sessions of the second condition A the mean was 92%.

EXPERIMENT 2

Experiment 1 demonstrated that differential reinforcement is an important factor in the acquisition of trace supraordinate stimulus control. This suggests that trace supraordinate stimulus control procedures may be viewed as a subset of more traditional stimulus control procedures. Another important determinant of stimulus control is the response-reinforcer contingency. Nevin (1973) reviews literature demonstrating that stimulus control established by response-independent reinforcement is not as strong as stimulus control established by response-dependent reinforcement. Nevin's rationale is that response-dependent reinforcement "...is likely to establish some superstitious pattern of behavior as a result of accidental correlations of particular movements and reinforcement" (p. 126) and that these behaviors are likely to be incompatible with keypecking, the traditional response used to measure stimulus control. It is possible that response-independent reinforcement may also reduce trace supraordinate stimulus control of DMTS performance.

Experiment 2 investigated the possibility that the response-reinforcer contingency is an important determinant of trace supraordinate stimulus control by comparing response-dependent, C-cue, and Response-Independent, RI-cue, conditions in a DMTS procedure.

Method

Subjects

The four White Carneaux pigeons that served in Experiment 1 also served in this experiment. Two pigeons with previous and extensive DMTS experience were also included.

Apparatus

See Experiment 1.

Procedure

The basic DMTS procedure with trace supraordinate stimuli described in Experiment 1 was employed with the following modifications. Immediately following Experiment 1, the UC-cued trials were altered from terminating with unconditional discriminative stimuli and response-dependent reinforcement to terminating with response-independent presentations of mixed grain. The white equilateral triangle keylight stimulus was therefore an RI-cue, a trace supraordinate stimulus correlated with response-independent reinforcement. Denny's (1967) elicitation theory suggests that pigeons may approach the magazine following the RI-cue rather than remaining at the response keys. This behavior may then be adventitiously reinforced and effectively compete with the keypeck response required on probe trials. Therefore magazine approach was defined as interruptions of a photobeam within the magazine enclosure and was recorded during C-cued and RI-cued delay intervals.. The initial results indicated that one bird, P3777, approached the magazine enclosure on response-independent trials and that the other birds did not. Therefore, a second condition was added in which P3777 was required to peck the darkened center key for reinforcement and P3513 was required to interrupt the magazine photobeam for reinforcement. These behaviors replaced the response-independent

reinforcement contingency on RI-cued trials. Accordingly, the trace supraordinate stimulus correlated with these two conditions was redesignated K-cue and M-cue, respectively.

Results

Figure 2 shows percentage correct matching responses during test sessions on RI-cued trials, open circles, and on baseline C-cued trials, closed circles. As Figure 2 indicates response-independent reinforcement did not disrupt probe-trial matching performance. Matching accuracies on probe trials ranged from means of 85% to 95%. Table 4 presents delay interval keypeck data and magazine approach data. These pigeons did not develop magazine approach behavior and showed no disruption of matching performance.

Figure 3 shows the matching performance of the two pigeons that completed both conditions of the present experiment. The RI-cued condition was divided into K-cues and M-cues to indicate the conditions in which the birds remained oriented at the Key and conditions in which the birds approached the Magazine. The upper left panel of Figure 3 shows that P3513 maintained probe trial matching accuracies of 100% on the probe trials of all five test sessions in the K-cued condition. P3777 was required to peck the darkened center key during K-cued delay intervals and accurate matching performance on probe trials resulted. The lower left panel of Figure 3 shows the matching performance of P3777 in the K-cue condition. The overall mean correct responses for P3777 on these K-cued probe trials was 80%. The upper right panel of Figure 3 shows that when required to approach the magazine during M-cued delay intervals P3513 failed to maintain accurate matching performance on probe trials. The mean correct responses

Figure 2. Matching performance in the RI-cued condition. Open circles are from RI-cued probe trials. Closed circles are from baseline C-cued trials.

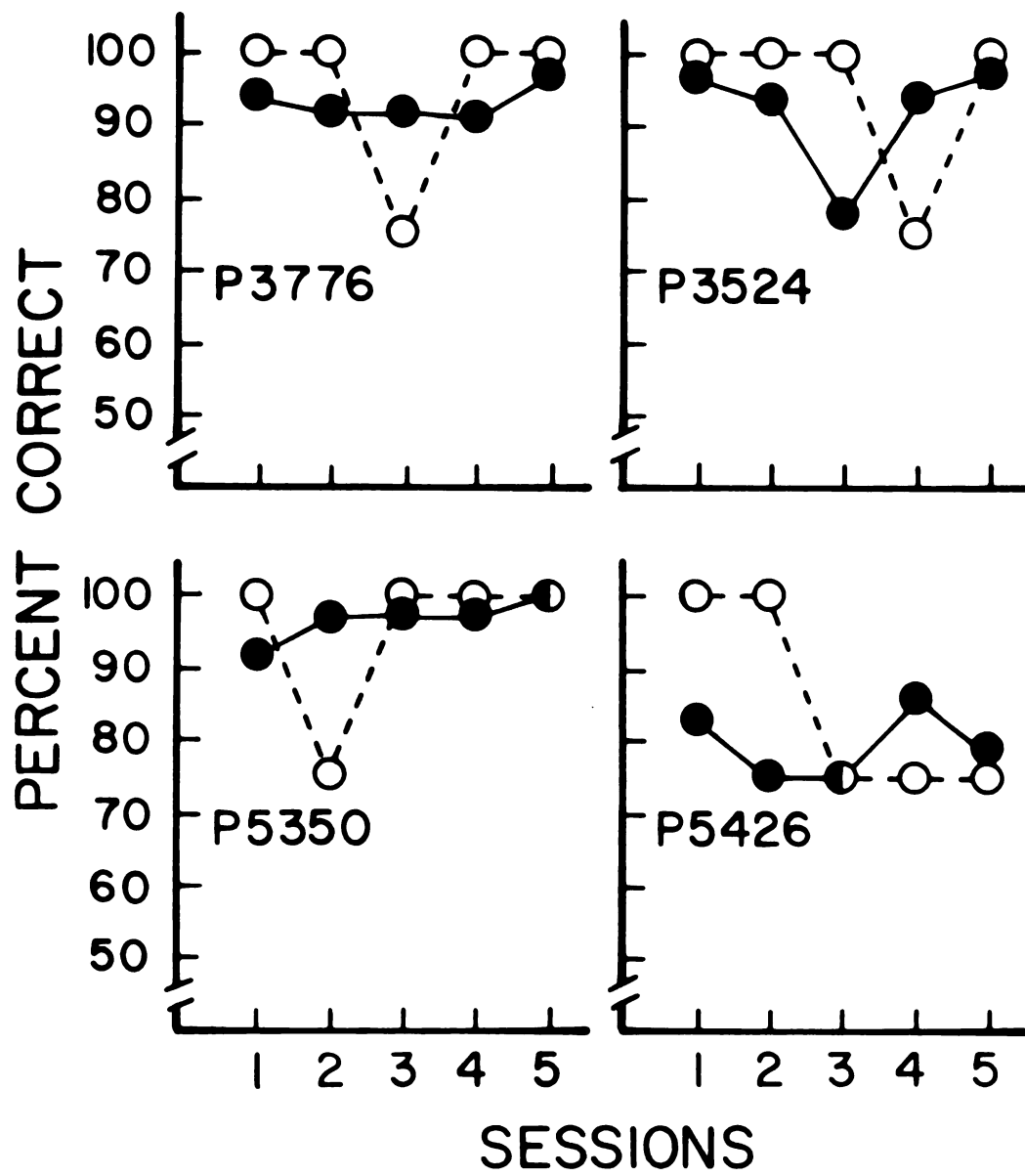


Table 4
Summary of Matching Performance Data

	P3776			P3524			P5350			P5426							
	Mean %	Correct	SE	C	RI	Mean %	Correct	SE	C	RI	Mean %	Correct	SE	C	RI		
5-day Baseline	94.4	1.91	0	0	0	97.6	1.12	0	0	96.4	1.47	0	0	89.0	1.64	0	0
Test																	
Baseline	93.4	0.98	0	0	0	92.0	3.56	0	0	96.6	1.29	0	0	79.4	2.20	0	0
Test																	
Probes	95.0	5.00	-	-	-	95.0	5.00	-	-	95.0	5.00	-	-	85.0	17.42	-	-

*SE, Standard error; C, C-cue; RI, RI-cue. Data are based on the means of five sessions.
Test Probes C and RI values were not recorded separately from Test Baseline.

for P3513 on M-cued probe trials was 55%. P3777 developed magazine approach behavior in the RI-cued condition and matching performance was disrupted on probe trials, declining to 60%. This is shown in the lower right panel of Figure 3.

Table 5 presents the mean matching accuracies, magazine approach behavior, and delay interval keypeck data for these two birds in both the K-cued and M-cued conditions. The combined results of the RI-cued condition and the K- and M-cued conditions demonstrate that remaining oriented at the response keys, whether adventitiously developed or experimentally manipulated, reduced trace supraordinate stimulus control. Matching accuracy averaged over the 4 pigeons in the RI-cued condition and P3513 and P3777 in the K-cued condition (remaining oriented at the response keys) was 89.3%. In contrast, orienting away from the response keys increased trace supraordinate stimulus control. Matching accuracy averaged over the two pigeons completing the M-cued condition (orienting away from the response keys), P3513 and P3777, was 57.5%.

Figure 3. Matching performance in the K-cued and the M-cued conditions. Open circles are from probe trials. Closed circles are from baseline trials.

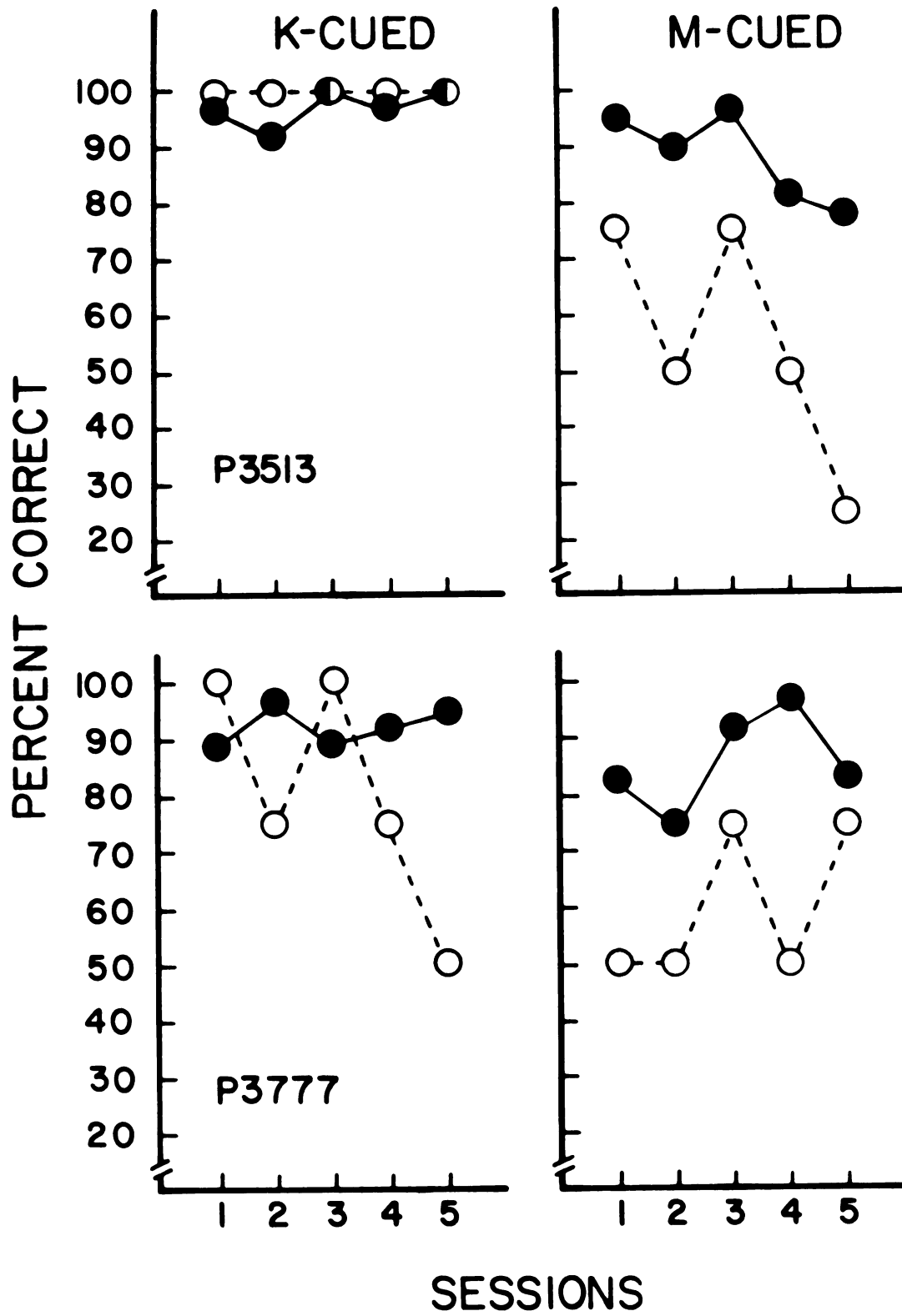


Table 5

Summary of Matching Performance Data

	K-cued						M-cued					
	P3513			P3777			P3513			P3777		
	Mean % Correct	SE	C	K	Mean % Correct	SE	C	K	Mean % Correct	SE	C	M
5-day Baseline Test	97.0	1.34	0	0	91.2	1.83	0	0	92.8	2.89	0	9
Baseline Test	97.2	1.46	0	0	92.2	1.53	0	0	87.8	3.65	1	24
Probes	100.0	0.00	-	-	80.0	9.35	-	-	45.0	18.37	-	-

*

SE, standard error; C, Cue-cue; K- K-cue; M, M-cue; data are based on the means of five sessions.
Test Proves C and K and M values were not recorded separately from Test Baseline.

EXPERIMENT 3

Nevin's (1973) suggestion that response-independent reinforcement weakens stimulus control through the adventitious acquisition of competing responses was supported in Experiment 2, at least in terms of trace supraordinate stimulus control. In Experiment 2, the RI-cued condition apparently provided adventitious reinforcement or orienting towards the stimulus panel for most of the pigeons; the same behavior that occurred during C-cued delay intervals. Therefore, both trace supraordinate stimuli were correlated with similar behaviors and similar DMTS performance was obtained. In P3777 magazine approach behavior was apparently adventitiously reinforced. Since that behavior differed from that occurring during C-cued delay intervals, the reduced matching performance on probe trials may have been due to response competition. That is, the M-cue may have set the occasion for magazine approach responses which effectively competed with accurate keypecking responses required on probe trials. The second condition of Experiment 2 provided experimental support for this analysis by demonstrating that manipulation of conditions that reversed the delay interval behaviors resulted in a similar reversal of DMTS performance.

The pattern of results obtained in these first two experiments suggest that when experimental contingencies produce differential delay interval behaviors trace supraordinate stimulus control is strengthened and when experimental contingencies produce nondifferential delay interval behaviors, trace supraordinate stimulus control is weakened.

Table 6 presents the behaviors occurring during each of the DMTS trial events as a function of the type of trial. Table 6 reveals that when behaviors that are present at the end of the delay interval or that are required for the delivery of reinforcement at the end of a trial, were similar after both trace supraordinate stimuli, DMTS performance was accurate on probe trials and when behaviors at the end of the delay intervals differed, DMTS performance on probe trials was reduced relative to baseline performance. Therefore, the present data do not differentiate between control of differential delay interval behaviors and control of differential end of delay interval behaviors as the critical factor in the control of DMTS performance.

The purpose of Experiment 3 was to determine whether behaviors at the end of the delay interval are the primary factor in the establishment of trace supraordinate stimulus control of DMTS performance. This was accomplished by arranging contingencies such that after a magazine-unconditional trace supraordinate stimulus, MUC-cue, interruption of the photobeam within the magazine enclosure produced unconditional discriminative stimuli and following the conditional trace supraordinate stimulus, C-cue, the comparison stimuli were presented. This procedure produces differential delay interval behaviors, i.e., magazine approach after the MUC-cue and orientation towards the response keys after the C-cue. This procedure also produces similar behaviors at the end of the delay intervals, i.e., peck the unconditional discriminative stimulus after the MUC-cue and peck the comparison stimulus after the C-cue. The behaviors generated by this procedure are also shown in Table 6. Chance performance on probe trials implicates differential delay interval behaviors as the critical factor in control of DMTS

Table 6
Correlations among trial events and behaviors

DMTS Trial Events				
Trial Types	Sample Stimulus	During Delay Intervals	End of Delay Intervals	Matching Performance
EXP 1 C-cued UC-cued NRFT-cued	Towards	Towards	Towards	Accurate
	Towards	Towards	Towards	Accurate
	Towards	Away	Away	Inaccurate
EXP 2 C-cued RI-cued K-cued M-cued	Towards	Towards	Towards	Accurate
	Towards	Equivocal	Equivocal	Equivocal
	Towards	Towards	Towards	Accurate
	Towards	Away	Away	Inaccurate
EXP 3 C-cued MUC-cued	Towards	Towards	Towards	Accurate
	Towards	Away	Towards	Accurate

* Towards, pecking or orienting towards the three response keys; Away, orienting away from the response keys, including magazine approach behavior.

performance since delay interval behaviors differ and matching behavior differs as a function of the trace supraordinate stimuli. Similar matching accuracies between probe trials and baseline trials implicates end of delay interval behaviors as the critical factor in control of DMTS performance since behaviors at the end of the delay intervals are similar and matching behavior is similar as a function of the trace supraordinate stimuli.

Method

Subjects

The two pigeons, P3513 and P3777, that completed both conditions of Experiment 2 served.

Apparatus

The apparatus of the previous experiments were used.

Procedure

All parameters, criterion, and testing procedures of the previous experiments were maintained for this experiment with the following modifications. Immediately after completion of Experiment 2 both birds were required to break the magazine photobeam upon termination of the 4 sec delay interval. One bird, P3777, was handshaped to approach and interrupt the photobeam. P3513 was performing this behavior as a result of training in Experiment 2. Interruptions of the photobeam initiated the simultaneous presentation of the vertical and horizontal bar unconditional discriminative stimuli used previously. A peck to the vertical bar produced reinforcement, 2.5 access to mixed grain.

On the UC-cued trials of Experiment 1, presentation of these unconditional discriminative stimuli was response-independent. In

this experiment presentation of the unconditional discriminative stimuli was contingent upon a magazine approach response after the 4 sec delay interval had timed out. Consequently, the trace supraordinate stimulus correlated with this condition, the white equilateral triangle, is referred to as a MUC-cue, indicating that a Magazine approach response produces the UnConditional discriminative stimuli. The C-cued trials were continued as in the previous experiments.

Results

Figure 4 shows the percentage correct matching responses on probe trials and baseline trials of the five test sessions. From Figure 4 it is apparent that P3513 performed accurately on probe trials, with an overall mean of 95% correct responses. P3777 performed somewhat less accurately with an overall mean of 85% correct, due primarily to 50% correct on test session four. These results suggest that DMTS performance was not disrupted, or disrupted only slightly, by delay interval magazine approach behavior. Table 7 presents summary data of matching percentages on the 5-day baseline measure, the test session baseline, and the probe trials and also presents the mean number of magazine approach behaviors per test session. Both birds increased magazine approaches from the pretest baseline to test sessions. P3777 did not approach the magazine as frequently as P3513, 19.8 mean times per session vs 43.4 mean times per session, respectively.

Figure 4. Matching performance in the MUC-cued condition. Open circles are from probe trials and the closed circles are from the baseline trials.

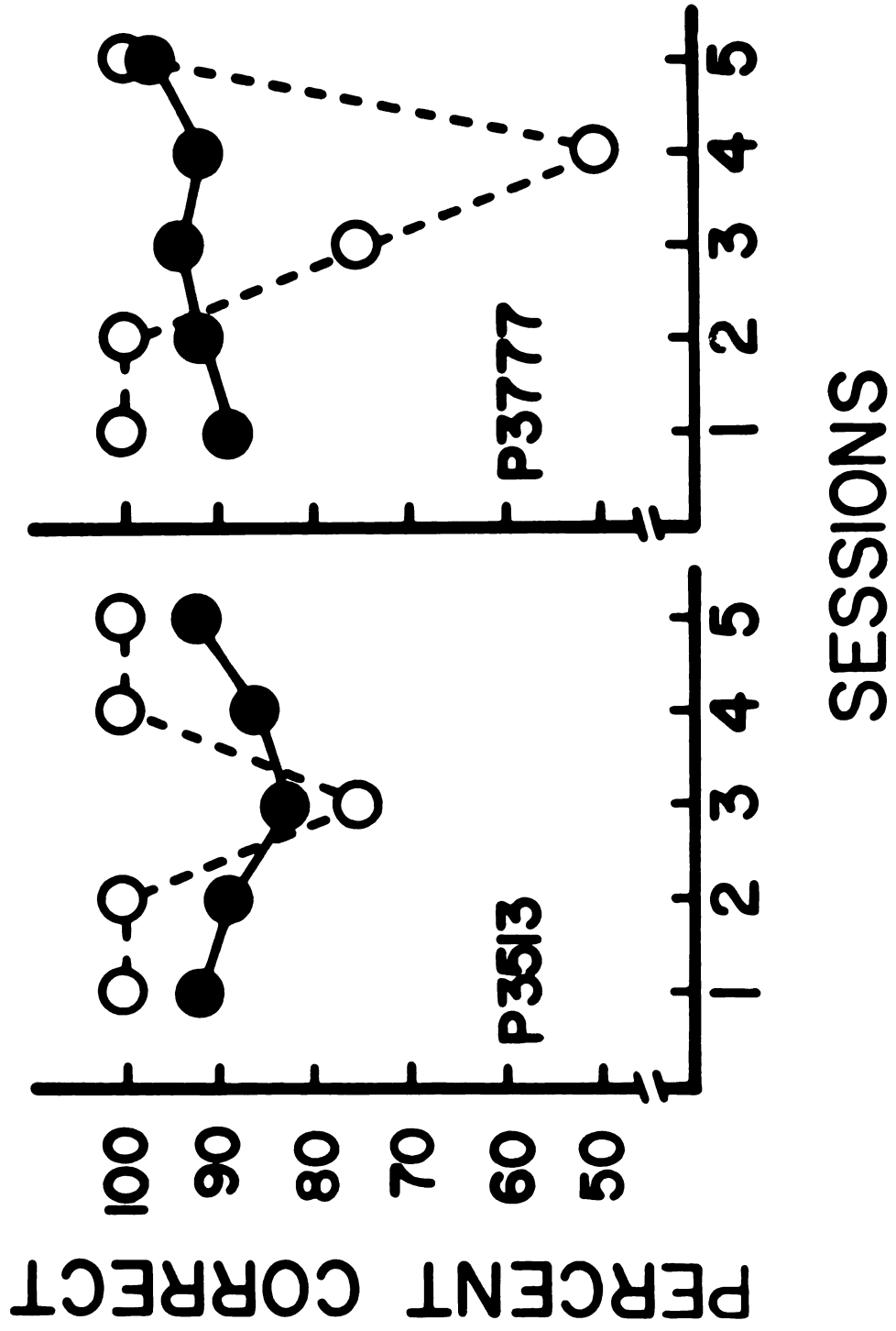


Table 7
Summary of Matching Performance Data

		P3513				P3777			
		Mean % Correct		SE	C	MUC	Mean % Correct	SE	C MUC
5-day Baseline Test		86.2	1.98	0	32	93.0	1.00	0	10
Baseline Test		88.4	1.75	0	43	92.8	1.32	0	20
Probes		95.0	5.00	-	-	85.0	10.00	-	-

* SE, standard error; C, C-cue; MUC, MUC-cue; data are based on the means of five sessions. Test Probes C and MUC values were not recorded separately from Test Baseline.

Discussion

Experiment 1 compared differential and nondifferential reinforcement correlated with trace supraordinate stimuli. When both trace supraordinate stimuli were correlated with reinforcement contingencies, C- and UC-cues, conditional matching performance after both stimuli was accurate. When the two trace supraordinate stimuli were correlated with nondifferential reinforcement, C- and NRFT-cues, conditional matching performance following the stimulus correlated with nonreinforcement, NRFT-cue, was reduced to near chance. Conditional matching performance following the trace supraordinate stimulus correlated with reinforcement, C-cue, remained accurate. In the nondifferential reinforcement condition, the UC-cue signalled the occurrence of unconditional discriminative stimuli. Memory of the sample stimulus was not required to gain reinforcement since a single peck to the S+, the vertical bar, produced reinforcement regardless of the color of the sample stimulus. Yet, in this nondifferential reinforcement condition accurate matching performance was obtained, contrary to the prediction of a cognitive rehearsal position.

A stimulus control interpretation of the results of Experiment 1 was supported. According to this position, nondifferential reinforcement weakens stimulus control and weakens trace supraordinate stimulus control. Consequently, accurate matching performance following the UC-cue was predicted and was obtained in the nondifferential reinforcement condition. The results of the differential reinforcement condition

were also consistent with the stimulus control position in that differential reinforcement strengthens stimulus control thereby producing inaccurate performance after the NRFT-cue, as was obtained.

Experiment 2 extended the analysis of the similarity of stimulus control and trace supraordinate stimulus control by eliminating the response-reinforcer contingency in the nondifferential reinforcement condition. Experiment 2 also eliminated the unconditional discriminative stimuli following the trace supraordinate stimuli and presented response-independent reinforcement after the RI-cue. Since presentation of the comparison stimuli on probe trials was a novel event, a generalization decrement position based on the novelty of the presentation of comparison stimuli predicts chance performance under this condition. However, accurate matching was obtained failing to support this generalization decrement position.

The stimulus control position predicted accurate matching since response-independent reinforcement weakens stimulus control as was found. Informal observation indicated that all but one pigeon, 3777, remained oriented at the response keys, while 3777 approached the magazine enclosure. This behavior is consistent with Nevin's (1973) position that stimulus control is weakened by response-independent reinforcement through the adventitious reinforcement of competing responses (also see Skinner and Morse, 1957). In all birds, except 3777, orienting towards the response keys was apparently adventitiously reinforced and was not a competing behavior since it was the same behavior maintained on C-cued trials. For pigeon 3777 magazine approach behavior was adventitiously reinforced and was a competing behavior since it differed from that generated on C-cued trials.

Experiment 2 also explored this analysis of the role of behaviors generated by nondifferential reinforcement by comparing differential, C- and M-cues and nondifferential, C- and K-cues, delay interval behaviors correlated with trace supraordinate stimuli. It was found that when pigeons remained oriented toward the response keys, matching accuracies remained high. When the pigeons oriented away from the response keys, matching accuracies were reduced to near chance, thus supporting the response competition analysis. This suggests that trace supraordinate stimulus control of DMTS performance is not strengthened by differential reinforcement per se, rather stimulus control is strengthened because differential reinforcement increases the probability of differential behavior correlated with different stimuli. Weisman (1970) presents evidence indicating that differential response rates, rather than differential reinforcement frequency, is the important factor of discrimination training that establishes inhibitory stimulus control. The present data suggest that differential behavior also is the primary factor in the establishment of trace supraordinate stimulus control and that differential reinforcement is but one method of establishing differential behavior.

Experiment 3 demonstrated that the behaviors occurring at the end of the delay interval are critical for accurate matching performance, rather than behaviors during the delay interval. Matching performance was accurate on probe trials when similar behaviors at the end of the delay and different behaviors during the delay intervals were correlated with the differentially-cued delays. This result indicates that the consistent occurrence of differential behavioral chains is not always sufficient to establish stimulus control and suggests that the terminal link of behavioral chains is the behavior responsible for the

establishment of stimulus control. That is, it may be that behavioral chains with different topographies are equivalent to the extent that the terminal links are similar. The results indicate that when the behavior occurring at the end of the delay interval is similar in the presence of both stimuli accurate matching is obtained regardless of the specific topographies of the behavior during the delay intervals.

This finding illuminates the inconsistent correlation found between sample-specific mediating behavior and DMTS performance (see Carter and Werner, 1978, for a review). Hunter's (1913) early finding that maintenance of bodily orientation towards the stimuli facilitates delayed responding sparked a controversy that has continued to the present. Recently, Zentall, Hogan, Howard and Moore (1978) have noted that sample-specific behavior is highly consistent in some subjects, but is unidentifiable in others, even though all subjects exhibited similar DMTS performance. Also, some studies (e.g., Blough, 1959) report clear evidence of sample-specific behavior in all subjects with accurate matching performance, while other studies (e.g., Stonebraker, 1980) report no such correlation. The present data may resolve this controversy since they indicate that perhaps only the behavior at the end of the delay interval is correlated with matching performance. It is suggested that previous failures to find direct correlations between mediating behavior and DMTS performance is because consistent behaviors at the end of the delay intervals are responsible for accurate matching performance, rather than specific chains of behavior throughout the delay. In other words, maintenance of bodily orientation is not necessary for accurate performance, but appropriate orientation prior to testing is essential.

The present data may also enhance our understanding of underlying memory processes. Recently, notions of context-dependent retrieval of memories have been employed to describe a large body of both human and animal memory literature (Lett, 1978; Lewis, 1979; Spear, 1978). According to these notions accurate remembering occurs to the extent that conditions are similar between learning or acquisition (information input) and retention testing (information output). That is, retrieval of a target memory is more probable the more similar the conditions of training are to the conditions of testing. This analysis may also apply to the short-term remembering of the sample stimulus in DMTS. In the baseline condition of all experiments, C-cued trials, the pigeons maintained visual orientation towards the response keys and responded accurately to the comparison stimuli. Therefore, it may be that the presentation of the comparison stimuli was a retrieval cue for memory of the sample stimulus (see D'Amato and Worsham, 1974) only when the comparison stimuli were presented in the appropriate context; i.e., visual orientation towards the response keys. The test conditions manipulated the visual orientation of the pigeons and it was shown that when the birds were oriented towards the response keys matching performance was similar to matching performance on the C-cued trials, i.e., accurate. Whenever the comparison stimuli were presented in a context different from the C-cued context, i.e., visual orientation towards the keys, retrieval of the sample stimulus could not and did not occur because the supporting context was absent. This context retrieval hypothesis is also a generalization decrement hypothesis. The novel presentation of comparison stimuli, on probe trials, was viewed as a possible source of generalization decrement by Stonebraker (1980) and

was shown not to account for the data. The present position is that the behavior at the end of delay intervals is the primary source of generalization decrement, rather than the stimulus conditions. Generalization decrement does not occur in DMTS because of novel stimulus conditions, but because those novel stimulus conditions require responses different from those occasioned by prior stimulus conditions. In other words, when presented with two stimulus situations, each controlling opposing response tendencies, matching accuracy suffers.

The present experiments have demonstrated the similarity of stimulus control and trace supraordinate stimulus control. The present experiments also failed to support a cognitive, information-based, rehearsal position to account for animal memory behavior. The notion that stimulus control of DMTS is based on response competition at the time of testing rather than during the delay interval was supported. When trace supraordinate stimuli were correlated with different behaviors, performance suffered. But when they were correlated with similar behaviors, performance remained accurate. This finding suggests that end of delay interval behavior established during baseline must be maintained in the test conditions in order to obtain accurate DMTS performance. This finding also indicates that maintenance of specific behavioral chains is not necessary to obtain accurate DMTS performance. The present results also serve to extend recent formulations of memory retrieval processes. It is suggested that in the present experiments bodily orientation towards the response keys may have established the visual context necessary for retrieval of a representation of the most recent sample stimulus, thereby affecting accurate matching.

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