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DELAYED MATCHING-TO-SAMPLE PERFORMANCE OF HENS: EFFECTS OF SAMPLE DURATION AND RESPONSE REQUIREMENTS DURING THE SAMPLE

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Six domestic hens were trained under a delayed matching-to-sample procedure with red and green keylights as sample and comparison stimuli and a 1.5-s delay interval. The hens were trained to stop pecking the sample stimuli when a tone sounded. Duration of the sample stimuli (2 to 10 s) and the number of pecks required on the key on which these stimuli were presented (0 to 10) were altered across conditions. Both the response requirement on the sample key and the duration of sample presentations affected accuracy. These findings are in agreement with those of earlier studies using other species and somewhat different procedures.

Key words: delayed matching to sample, sample duration, response requirement, key peck, domestic hens

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Researchers using delayed matching-to-sample (DMTS) procedures have examined the effects of a wide range of variables on remembering (McCarthy & White, 1987). One variable shown to influence DMTS performance in studies with pigeons is the response requirement arranged on the key on which the sample stimulus is presented (i.e., the sample key). In general, pigeons' accuracy in matching increases when a response is required on the sample key relative to conditions in which no response requirement is programmed, and increases further as the number of responses required on the sample key is increased (e.g., Lydersen, Perkins, & Chairez, 1977; Maki, Gillund, Hauge, & Siders, 1977; Maki, Moe, & Bierley, 1977; Roberts, 1972; Roberts & Kramer, 1982; White, 1985).

Increasing the duration of sample-stimulus presentations also increases accuracy under DMTS procedures (e.g., Farthing, Wagner, Gilmour, & Waxman, 1977; Grant, 1976; Guttenberger & Wasserman, 1985; Leith & Maki, 1975; Nelson & Wasserman, 1978; Roberts & Grant, 1974; Shimp & Moffitt, 1977). Duration of sample-stimulus presentations and sample-key response requirements are, however, characteristically confounded in studies ostensibly concerned with either variable alone. In studies of response requirements, the duration of the sample stimulus characteristically is determined by the time required to complete the programmed ratio. Therefore, as Maki, Gillund, Hauge, and Siders (1977) pointed out, increasing the response requirement on the sample key may improve performance wholly or in part by increasing the duration of sample-stimulus presentation. A similar point was made by Spetch and Treit (1986), who concluded that increasing sample-key response requirements increases accuracy primarily as a result of increased exposure to the sample rather than as a result of the effort required to respond.

The primary purpose of the present study was to examine the contributions of sample duration and sample-key response requirements to DMTS performance. Domestic chickens were used as subjects. This species has been reported to respond well and similarly to pigeons under matching-to-sample procedures with no delay (DeMello, Foster, & Temple, 1992, 1993). Moreover, unpublished data indicate that the two species also respond similarly under DMTS procedures (e.g., Carroll, 1989; Jones, 1988; Odey, 1991). In the present study, hens were initially trained to peck the sample stimulus until a tone was sounded and then to stop pecking for the remaining time the stimulus was on.

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One series of conditions involved no pecking on the sample, with the duration of the sample stimulus varied. If the hen responded during the sample, then that trial was aborted. The aim of this series was to determine the effects of sample duration alone. In the other conditions, requirements of 1, 3, 7, and 10 responses on the sample key were combined with stimulus durations of 2 s, 5 s, and 10 s. Trials were aborted unless exactly the required number of responses were completed while the sample stimulus was present. Care was taken to see that the required number of responses could be completed within the stimulus duration.

METHOD

Subjects

Six domestic hens, numbered 51 to 56, served as subjects. Hens 52 to 56 had previously served in DMTS experiments with the same stimuli used in the present study. Hen 51 was experimentally naive at the start of the experiment. All hens were maintained at approximately 80% of their free-feeding body weights by providing supplementary feeding of laying mash in their home cages following experimental sessions. Water and oyster-shell grit were freely available in their home cages. All hens had red and fleshy combs and occasionally laid eggs during the course of the study, suggesting that they were healthy.

Apparatus

The experimental chamber (670 mm wide by 414 mm deep by 570 mm high) was situated away from the solid-state programming equipment that controlled and recorded all experimental events. There were three response keys in the chamber, each 34 mm in diameter, arranged horizontally 48 mm apart and 380 mm from the grid floor. The keys could be illuminated by either red or green 1-W lights. Key pecks required a minimum force of 0.2 N, caused a 0.025-s feedback beep, and darkened the key for 0.025 s. Directly under the center key was an aperture that gave access to a food magazine. The magazine aperture could be illuminated alone or could be illuminated with the magazine raised to provide access to wheat. A 0.5-W white light (houselight), centrally located in the ceiling of the chamber, provided ambient illumination. When desired, a tone could be sounded inside the chamber via a speaker mounted on the rear wall.

Procedure

Hens 52 through 56, which had DMTS histories, initially were trained to stop pecking the center key when a tone sounded for 0.5 s. Pecking in Hen 51 initially was shaped by successive approximations; she was then exposed to the same training procedure as the other birds. During training, the center (sample) key was illuminated red or green for 5 s with the houselight on. When a bird pecked this key five times within 5 s, a tone sounded for 0.5 s, and the center keylight went out at the end of the 5-s sample presentation. After a delay (0.01 s during this initial training), the two side keys were illuminated, one red and one green. The side on which each color occurred was determined randomly. A single peck to the side key that matched the previous sample stimulus, termed a correct response, extinguished the keylights and produced either 3-s access to the raised and illuminated magazine or 3-s illumination of the magazine light. A single peck to the side key that did not match the previous comparison stimulus, termed an incorrect response, resulted in a 3-s darkening of all chamber lights. If the bird pecked the center key more or less than five times during the 5-s sample presentation, the trial ended after 5 s with a 3-s darkening of all chamber lights (blackout). Such trials were termed aborted trials. Regardless of the bird's performance, there was no intertrial interval; the next trial started as soon as food delivery, illumination of the magazine aperture, or darkening of the chamber ended.

Throughout the experiment, the availability of food following correct red and green responses was controlled by a variable-interval schedule with an average interval of 15 s. A controlled reinforcement procedure was used. Thus, when food became available for one alternative (e.g., a correct response to red), the schedule stopped until that reinforcer was collected. Correct responses that did not produce food were followed by 3-s illumination of the magazine. The order of the colors presented on the sample key was pseudorandomly determined, with the restriction that each color could occur on no

Table 1

Sequence of experimental conditions for all subjects. The number of sample-key responses required and the sample duration under each condition are noted, as is the number of sessions of exposure.

Condition	Sample-key responses	Sample duration (s)	Number of sessions
1	3	5	20
2	1	5	33
Training	—	5	15
3	7	5	41
4	3	2	40
5	1	2	35
Training	—	10	14
6	3	10	33
7	1	10	53
Training	—	10	8
8	7	10	21
9	10	10	31
10	3	5	25
Training	—	2	18
11	0	2	27
12	0	5	31
13	0	10	34

more than three consecutive trials. The probability of a red or a green sample stimulus occurring on any trial was as close as possible to .5. In all conditions of the experiment, a single daily session was conducted for each subject 5 days per week, at about the same time each day.

The initial training conditions were in effect for 62 sessions. The number of sample-key pecks required was then reduced to three, with the sample duration unchanged at 5 s. After 28 sessions, the interval from the offset of the sample stimulus to the onset of the comparison stimuli was increased in 0.25-s steps over the next 42 sessions to 1.25 s. The delay was then increased to 1.5 s for the rest of the experiment. At this point, the experiment proper began. Each daily session during the experiment proper terminated after 30 or 31 deliveries of wheat for Hens 52 through 56. For Hen 51, sessions were terminated after 40 min if 30 wheat deliveries had not been obtained.

Performance of each hen was examined across 13 conditions, in which sample-key response requirements and sample durations were varied. Response requirements of 0, 1, 3, 7, and 10 and stimulus durations of 2 s, 5 s, and 10 s were used, although not all possible combinations were examined. Table 1 shows the order of experimental conditions and the response requirements and sample durations during each condition. Additional training, gradually increasing or decreasing the number of responses required to the sample key, took place between some conditions. When this training occurred and the number of days it was in effect are shown in Table 1.

Each condition continued until two criteria were met by all subjects. One required that there be no visually evident trend in accuracy across sessions. The other required that the median of the last five sessions' proportions correct for each subject be within .05 of the median of the preceding five sessions' data on five, not necessarily consecutive, occasions. Table 1 shows the number of sessions required to meet these criteria under each condition.

The numbers of correct and incorrect left and right side-key responses following both red- and green-sample trials were recorded each session, together with the number of wheat deliveries following red-sample trials and the total number of wheat deliveries. The number of trials aborted due to insufficient responses and the total number of trials aborted also were recorded.

Data Analysis

Most data from DMTS studies have been analyzed in terms of the percentage of correct responding. This measure potentially confounds the discriminability of the stimuli with any response bias toward a particular stimulus. To separate these sources of control, Davison and Tustin (1978) proposed an extension of the generalized matching equation, which was used to analyze the present data. Describing DMTS data in the manner proposed by Davison and Tustin is advantageous in that it allows for calculation of an unbiased estimate of the discriminability of the two stimuli, log *d*, and an estimate of any inherent bias the organism may have for a particular stimulus, log *c*. To calculate these measures, events in the DMTS procedure are categorized as in Figure 1. The numbers of responses obtained in each cell are designated B_w, B_x, B_y, and B_z, and the numbers of reinforcers are designated R_w, R_x, R_y, and R_z. Davison and Tustin suggested that the behavior following presentation of one sample stimulus, S_1, may be described as

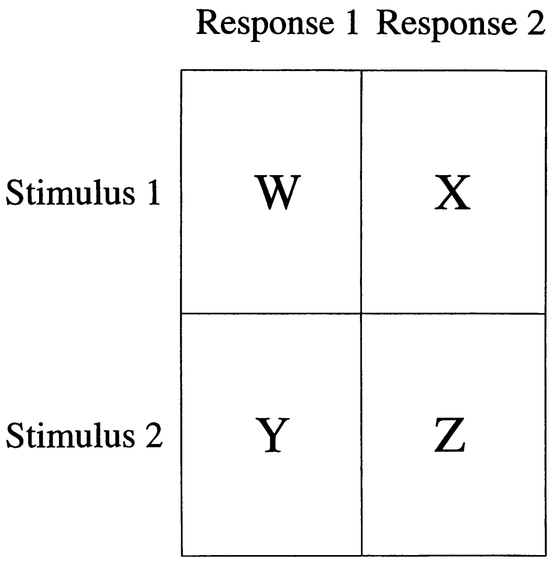

Fig. 1. Possible events under a DMTS procedure as used in the present experiment. Stimulus 1 and Stimulus 2 designate the two comparison stimuli presented on a given trial (red, green), Response 1 and Response 2 designate the two responses possible on a given trial (peck red, peck green), and the letters W, X, Y, and Z denote the number of events (responses and reinforcers) occurring in each cell.

$$\log(B/B_x) = a \log(R_w/R_z) + \log c + \log d, \quad (1)$$

and that behavior following the presentation of the other stimulus, S_2, may be described as

$$\log(B_y/B_z) = a \log(R_w/R_z) + \log c - \log d. \quad (2)$$

The parameter a measures the sensitivity of changes in the behavior ratio to changes in the reinforcement ratio, log c gives a measure of inherent bias, and log d provides a measure of the discriminability of the sample stimuli. A point estimate of log d can be obtained by subtracting Equation 2 from Equation 1 to get

$$\log d = 0.5 \log[(B_w \cdot B_z)/(B_x \cdot B_y)]. \quad (3)$$

An estimate of overall bias, which combines the bias due to any reinforcement asymmetry and inherent bias and which is independent of discriminability, can be obtained by adding Equations 1 and 2 to get

$$0.5 \log[(B_w \cdot B_y)/(B_x \cdot B_z)] = a \log(R_w/R_z) + \log c. \quad (4)$$

Controlling reinforcement frequencies, so that the ratio of R_w to R_z is 1.00, provides a behavioral measure of inherent bias, log c. When log c equals zero, percentage correct and log d will covary directly, but not necessarily linearly. The relationship is not necessarily linear, because percentage correct has an upper limit (100%) whereas log d does not.

Further discussion of the use of the generalized matching equation in analyzing DMTS performance is provided by Davison and McCarthy (1988) and McCarthy and White (1987). Because some readers will be more familiar with DMTS data expressed as percentage control, a summary of the present findings expressed in this way is provided in Appendix A, although these data are not discussed herein. The data from which log d and percentage correct measures were derived are provided in Appendixes B and C.

RESULTS

For each subject, data summed over the last five sessions of each condition were used in the following analyses. Figure 2 shows the point estimates of log d, calculated using Equation 3, for each condition for each subject plotted as a function of the response requirement on the sample key. Only completed trials were used in this calculation. The lines join data from conditions with the same sample-stimulus durations. The figure shows that log d generally increased as the response requirement increased. This relation held for all of the 18 functions shown. Log d usually was higher at the longer sample-stimulus durations, but the functions for different sample durations overlap considerably.

Figure 3 shows the same data plotted as a function of the sample-stimulus duration. The lines join data from conditions with the same response requirements. This figure shows that, in general, as the sample-stimulus duration increased at any one response requirement, so did log d. In addition, for most subjects, the functions at each response requirement show reasonably clear separation, being higher with larger sample-key response requirements.

In summary, visual analysis of the data in Figures 2 and 3 shows that DMTS performance became more accurate with increases

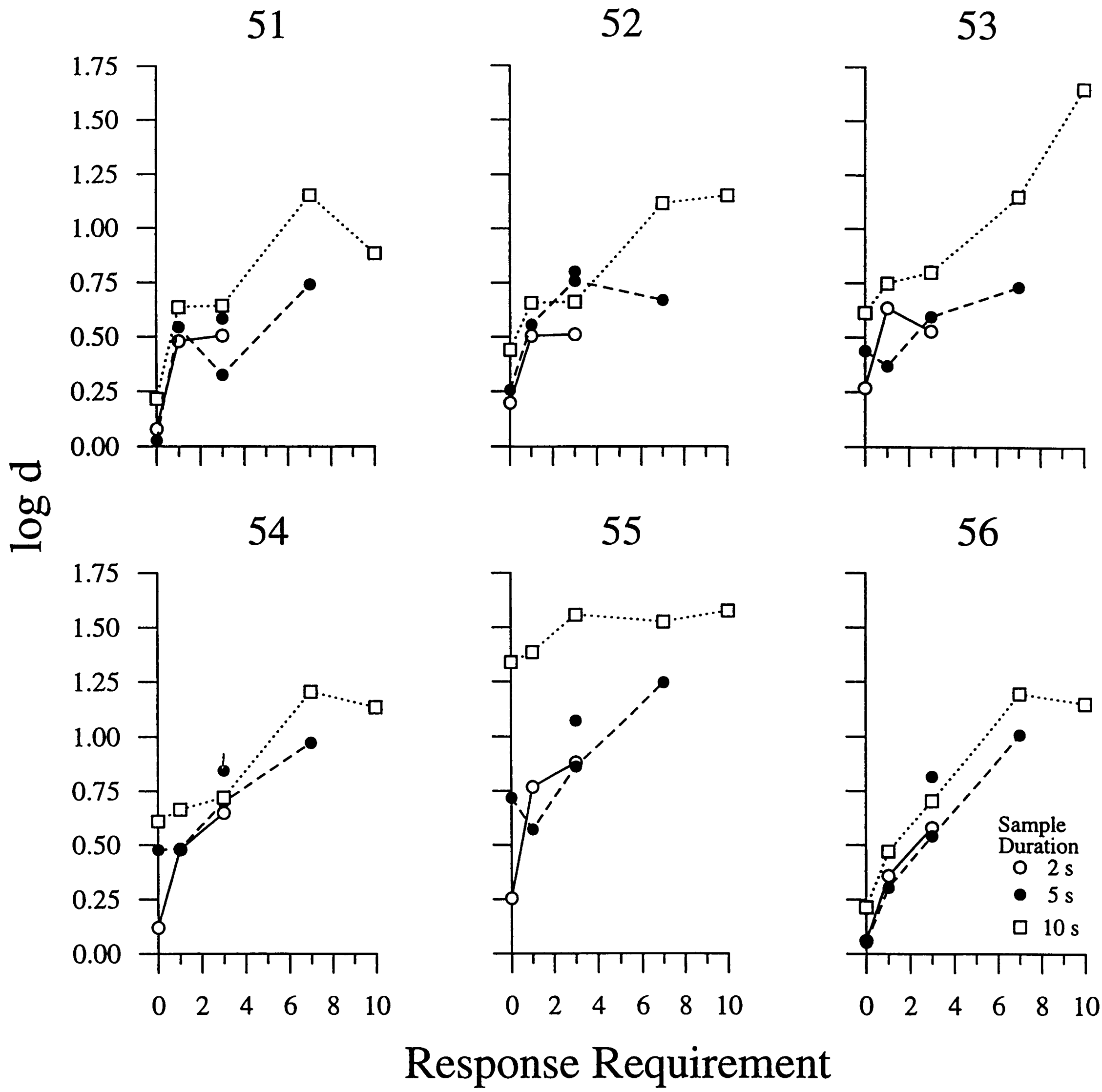

Fig. 2. Log *d* values for 6 individual hens, calculated as described in the text, as a function of the response requirement programmed on the sample key under a DMTS procedure. Separate data paths are presented for each of three sample durations. One condition (3-s sample duration, FR 3 response requirement) was replicated; the data point for the replication is not connected to other points.

in both the sample-stimulus duration and the response requirement. To quantify these relations, regression lines were fitted by the method of least squares to these data. Slopes of these lines, shown in Table 2, provide an indication of the relative effects on accuracy of increasing sample duration at particular response requirements and of increasing fixed-ratio (FR) size at particular sample durations.

Slopes differed considerably across hens under a given condition. All slopes were positive, indicating that accuracy (log *d*) always increased with increases in sample duration and FR size. Slopes indexing the effects of sample duration did not change in graded fashion as a function of FR size. In 5 of 6 hens (55 was the exception), the effects of sample duration on accuracy (i.e., slopes) were greatest when the FR size was seven. There were

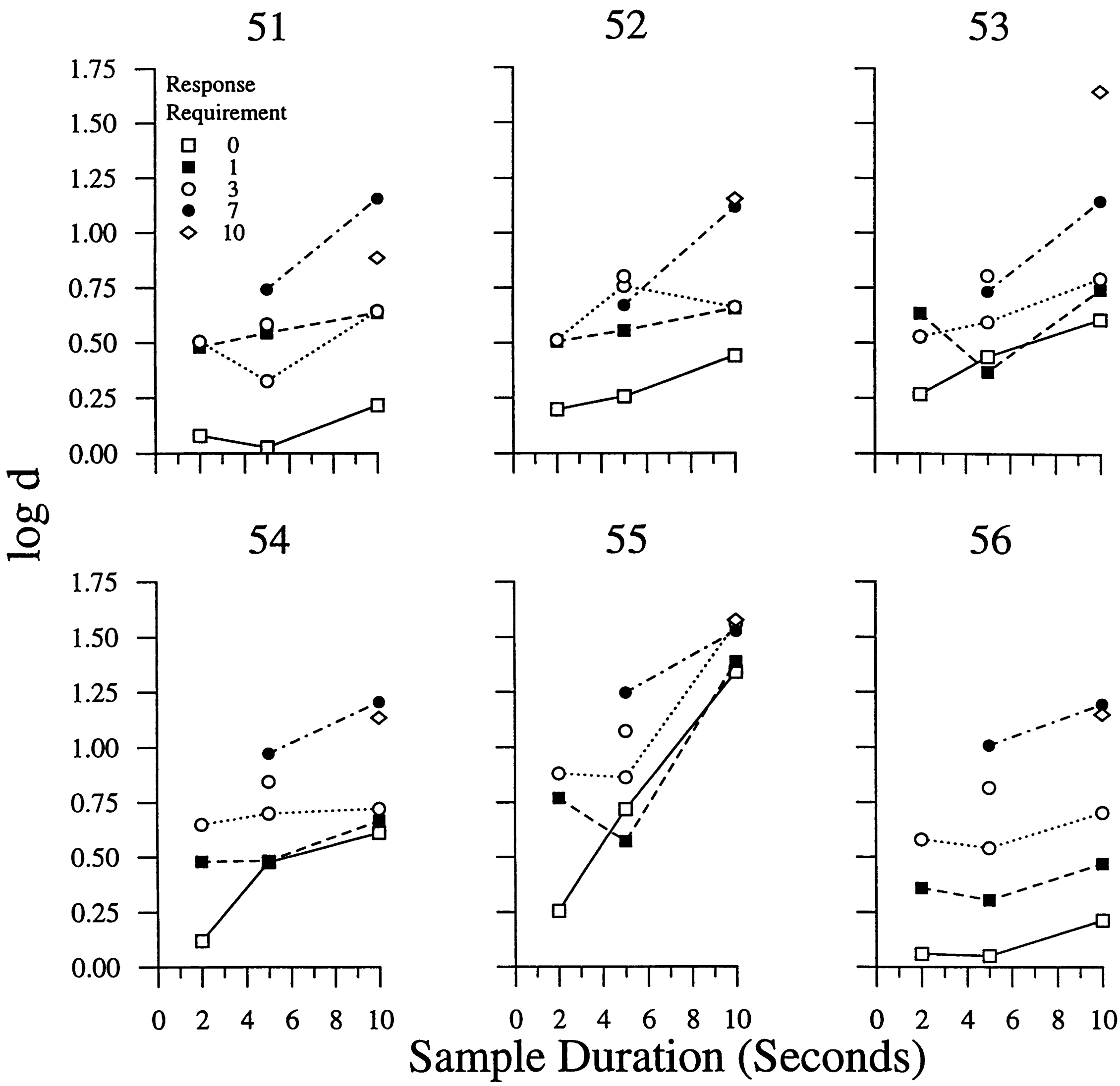

Fig. 3. Log *d* values for 6 individual hens, calculated as described in the text, as a function of the stimulus duration on the sample key under a DMTS procedure. Separate data paths are presented for each of three sample durations. One condition (3-s sample duration, FR 3 response requirement) was replicated; the data point for the replication is not connected to other points.

only two data points for each bird at FR 7, however, so slopes at this value should be interpreted with caution.

In 5 of 6 hens (not 53), slopes indexing the effects of FR size on accuracy were greatest when the sample duration was 2 s. In 4 of these birds (not 52), slopes decreased progressively as the sample duration increased. These data indicate that the effects of FR size and sample duration were not completely independent but interacted somewhat.

A controlled reinforcement procedure was used in the present study; as a result, there were almost exactly equal numbers of reinforcements for correct responses to red and green stimuli in each condition. Point estimates of inherent bias, log *c*, were calculated using Equation 4 and taking the ratios of the

Table 2

Slopes of regression lines fitted to data plotted as the effects on accuracy (log *d*) of increasing sample duration at particular FR values (upper section) and of increasing FR size at particular sample durations (lower section).

		Hen						
		51	52	53	54	55	56	*M*
FR size	0	0.19	0.31	0.42	0.58	1.34	0.24	0.51
	1	0.19	0.19	0.21	0.24	0.86	0.16	0.31
	3	0.20	0.12	0.32	0.06	0.90	0.14	0.29
	7	0.83	0.89	0.86	0.90	0.55	0.37	0.73
Sample duration	2 s	1.23	0.90	0.66	1.63	1.87	1.65	1.32
	5 s	0.78	0.49	0.51	0.76	0.90	1.33	0.80
	10 s	0.66	0.72	0.98	0.62	0.21	0.96	0.69

numbers of reinforcements to be 1.0. The estimates were found to be near zero for all subjects in all conditions; they did not change across response requirements or sample durations.

Throughout the experiment, trials were aborted when there were too few or too many responses during the sample presentations. Figure 4 shows the percentage of trials aborted for each sample duration as a function of the response requirement for each bird. In general, about 40% to 50% of trials were aborted by all birds under most conditions. The aborted-trials data for Hen 51 are the exception, being much higher under most conditions. For all birds, the number of aborted trials generally increased as the response requirement increased. Further analysis of the aborted-trials data showed that this was a product of increases in the number of trials aborted as a result of too few pecks. The percentage of trials with too few pecks did not increase or decrease systematically as the sample duration increased. For all subjects, there were fewer trials aborted due to too many pecks than due to too few pecks, and the relative number of trials with too many pecks was not obviously related to either response requirement or sample duration.

Comparing the data in Figure 4 to those in Figures 2 and 3 suggests that log *d* generally increased as the number of aborted trials increased. To determine the quantitative extent of the relationship between aborted trials and accuracy, a Pearson product-moment correlation coeffecient was calculated between log *d* and percentage aborted trials across all experimental conditions. The resultant r was .48 ($df = 76$). Although this value is significant at $\alpha < .01$, variation in the percentage of aborted trials accounted for only 23% of the variance in accuracy.

DISCUSSION

The present study supports unpublished findings that indicate that domestic hens perform relatively well, and similarly to pigeons, under DMTS procedures (e.g., Carroll, 1989; Jones, 1988; Odey, 1991). A prior study reported that increasing the sample-key requirement from 1 to 5 and 10 progressively increased log *d* values in hens performing a visual acuity task under a matching-to-sample procedure with no delay, although further increases in response requirements did not consistently increase performance (DeMello et al., 1993). Response requirements above 10 were not examined in the present study, in which log *d* increased with sample-key response requirements; thus, the present findings are consistent with those of DeMello et al. (1993).

Prior studies with species other than chickens have demonstrated that DMTS accuracy improves when either sample durations or sample-key response requirements increase (e.g., Farthing et al., 1977; Grant, 1976; Guttenberger & Wasserman, 1985; Leith & Maki, 1975; Lydersen et al., 1977; Maki, Gillund, Hauge, & Siders, 1977; Maki, Moe, & Bierley, 1977; Nelson & Wasserman, 1978; Roberts, 1972; Roberts & Grant, 1974; Roberts & Kramer, 1982; Shimp & Moffitt, 1977; White, 1985). Similar findings were reproduced with chickens in the present study. The present study differed procedurally from prior investigations by neither allowing the sample du-

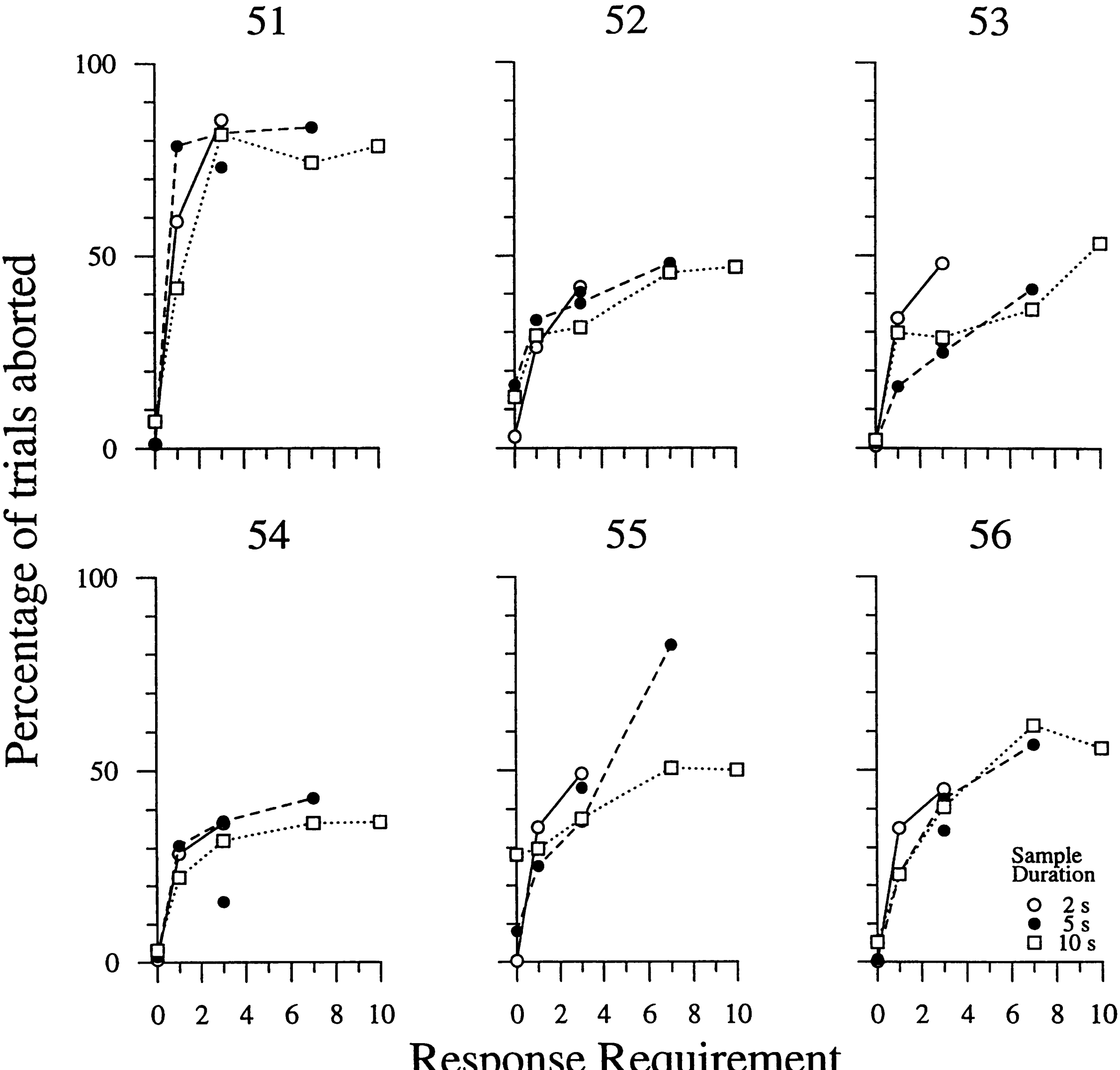

Fig. 4. Percentage of trials aborted for 6 individual hens under all experimental conditions. A trial was aborted if a hen pecked the sample key more or less often than the indicated response requirement while the sample key was illuminated.

ration to vary as a function of response requirements nor allowing the number of sample-key responses to vary as a function of sample duration. Unless this is done, it is possible that the effects of increasing sample duration actually result from increased responding or, similarly, that the effects of increasing sample-key response requirements result from longer sample presentations. Neither of these confounding effects was possible in the present study, which provides evidence that sample duration and sample-key response requirements directly and independently affect DMTS performance.

Because response requirements and sample durations are scaled along different dimensions, it is impossible to compare the magnitude of their effects in a meaningful way. It is perhaps noteworthy that sample duration produced any detectable effects on accuracy in the present study. Under the procedures used, if few responses were required and the sample duration was rather long, the bird may have kept from responding by turning away from the sample stimulus, thereby lessening the actual period of exposure to (sensory contact with) the stimulus. We did not observe the hens to determine whether they turned away from the sample stimulus after completing the ratio requirement but, even if such behavior did occur, it did not prevent nominal sample duration from affecting accuracy.

Several theoretical models of DMTS performance have been developed, but their adequacy in accounting for the present findings is difficult to determine. For example, Roberts (1972) and Roberts and Grant (1976) proposed that DMTS performance is the result of comparisons of the test stimuli with a gradually decaying internal analogue (trace) of the sample stimulus. It has been suggested that trace strength is a positive function of sample duration and a negative function of time since sample offset (Guttenberger & Wasserman, 1985; Roberts, 1972; Spetch & Treit, 1986).

Responding to the sample stimulus might also increase trace strength. It could be reasonably proposed that it is not the time that a sample stimulus is presented per se that determines trace strength but rather the time that an organism attends to that stimulus. Imposing a response requirement on the sample key requires attention to that key, and increasing the response requirement may increase the time of forced attention. Incidentally, it is not necessary to infer a decaying trace to account for the effects of increased attention on performance. In a review of studies in which multiple responses to a training stimulus resulted in greater discrimination, Honig and Urcuioli (1981) proposed that attention to the stimulus dimension under investigation is enhanced through repetitive responding by reducing competition from other stimuli. Perhaps this mechanism accounted, at least in part, for the effects of increasing response requirements in the present study.

Sacks, Kamil, and Mack (1972) proposed that increasing either response requirements or sample durations increases accuracy by increasing the relative costliness of incorrect responding. Log d data from the present study are consistent with this analysis, but aborted-trials data are not. Although the hens became more accurate on completed trials as response requirements increased, they became less accurate in completing the response requirements. Trials with larger response requirements require more effort; hence, a failure to complete such a trial successfully once some responding has occurred is in a sense more costly than erring on a trial with lower response requirements. Therefore, according to the analysis proposed by Sacks et al., accuracy in completing the sample-key response requirement should have increased, not decreased, as a function of increasing the sample-key response requirement.

In general, DMTS accuracy in the present study increased as the percentage of aborted trials increased, although variation in the latter variable accounted for less than 25% of the total variance. In general, DMTS accuracy improves as the intertrial interval is increased (e.g., D'Amato, 1973; Grant, 1976), and it is possible that aborted trials in the present study, which did not present both sample and comparison stimuli, were functionally equivalent to intertrial periods.

Examining DMTS data in terms of the generalized matching law, as was done in the present study, allows for a finer grained analysis than examining such data in terms of percentage of correct responding (Davison & McCarthy, 1988; Davison & Tustin, 1978; McCarthy & White, 1987). The conclusions supported by the two kinds of analyses do not necessarily agree, but they do so in the case of the present data. For the present data, estimates of inherent bias were close to zero and did not change across conditions. Therefore, changes in log d values closely approximated changes in overall percentage of correct responding values and support equivalent conclusions. Such an outcome is not foregone, however, and describing DMTS data in the manner proposed by Davison and Tustin may well prove to be advantageous in future studies.

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APPENDIX A

Mean percentage correct by each hen during the last five sessions of exposure to all experimental conditions.

	Sample duration											
	2 s			5 s				10 s				
Hen	FR 0	FR 1	FR 3	FR 0	FR 1	FR 3	FR 7	FR 0	FR 1	FR 3	FR 7	FR 10
51	55	75	76	52	77	67, 79	84	62	81	81	93	89
52	61	76	76	64	78	85, 86	82	73	81	82	98	91
53	65	81	76	70	70	80, 87	84	80	85	86	94	98
54	57	75	82	75	75	83, 86	90	80	82	84	94	93
55	64	85	88	84	79	87, 92	94	96	96	97	97	97
56	54	70	79	53	67	77, 87	91	62	75	83	94	93

APPENDIX B

Raw data from which log *d* and percentage correct measures were derived. All data are totals for individual hens across the final five sessions of exposure to the listed condition.

Condition	FR	Sample (s)	Trials aborted with too few responses	Total trials aborted	Correct responses		Incorrect responses	
					Red on left key	Red on right key	Red on left key	Red on right key
1	3	5	939	1,175	52	28	33	2
1	3	5	166	249	87	82	19	11
1	3	5	138	162	97	78	37	16
1	3	5	206	243	76	87	14	23
1	3	5	116	245	95	87	12	8
1	3	5	235	288	78	74	11	26
2	1	5	878	1,047	62	38	34	4
2	1	5	126	220	60	100	15	39
2	1	5	66	102	107	79	60	20
2	1	5	169	211	56	110	17	56
2	1	5	97	148	85	78	24	29
2	1	5	146	163	54	143	15	73
3	7	5	1,134	1,239	60	46	7	8
3	7	5	325	355	75	85	24	7
3	7	5	257	283	80	94	14	8
3	7	5	255	263	71	95	5	14
3	7	5	1,160	1,174	69	62	6	3
3	7	5	412	454	71	78	1	11
4	3	2	2,006	2,070	70	49	41	9
4	3	2	314	350	104	64	43	22
4	3	2	318	387	82	93	22	8
4	3	2	230	264	75	100	23	25
4	3	2	383	412	76	117	14	14
4	3	2	346	390	81	111	5	49
5	1	2	516	671	105	63	55	3
5	1	2	164	185	117	88	42	20
5	1	2	217	259	115	110	24	20
5	1	2	163	221	83	121	18	47
5	1	2	201	244	106	82	24	15
5	1	2	296	317	72	134	16	72
6	3	10	281	1,036	51	36	10	9
6	3	10	91	179	55	91	12	32
6	3	10	55	154	71	85	15	22
6	3	10	133	188	73	86	12	21
6	3	10	96	190	83	66	3	6
6	3	10	172	277	66	101	5	35
7	1	10	171	276	93	66	28	7
7	1	10	131	176	62	99	10	41
7	1	10	138	169	80	77	21	10

APPENDIX B

(Continued)

Condition	FR	Sample (s)	Trials aborted with too few responses	Total trials aborted	Correct responses: Red on left key	Correct responses: Red on right key	Incorrect responses: Red on left key	Incorrect responses: Red on right key
7	1	10	97	128	87	105	19	24
7	1	10	113	142	82	86	7	43
7	1	10	42	141	67	130	17	40
8	7	10	508	809	79	61	11	3
8	7	10	186	281	79	69	11	16
8	7	10	128	209	91	82	10	3
8	7	10	165	176	64	77	6	3
8	7	10	269	323	89	71	4	3
8	7	10	490	525	81	75	9	3
9	10	10	619	914	54	47	14	1
9	10	10	240	291	71	62	12	15
9	10	10	348	378	62	68	1	2
9	10	10	186	187	68	65	7	10
9	10	10	267	300	71	78	0	5
9	10	10	368	436	93	89	7	6
10	3	5	906	961	57	73	6	22
10	3	5	199	274	64	82	8	22
10	3	5	110	152	92	71	17	7
10	3	5	59	85	91	90	5	34
10	3	5	197	302	89	71	10	8
10	3	5	156	210	90	82	14	14
11	0	2	0	9	144	65	122	38
11	0	2	0	20	51	144	19	112
11	0	2	0	4	73	110	49	94
11	0	2	0	5	33	158	26	139
11	0	2	0	2	151	54	111	20
11	0	2	0	1	43	145	44	150
12	0	5	0	7	124	45	134	22
12	0	5	0	112	70	101	44	64
12	0	5	0	7	61	85	44	78
12	0	5	0	7	64	119	15	43
12	0	5	0	40	120	69	32	0
12	0	5	0	5	123	48	111	55
13	0	10	0	40	98	70	70	37
13	0	10	0	69	51	113	7	48
13	0	10	0	9	71	85	28	23
13	0	10	0	14	96	86	14	29
13	0	10	0	165	93	80	9	3
13	0	10	0	29	75	88	53	45

APPENDIX C

Raw data from which log *d* and percentage correct measures were derived. All data are totals for individual hens across the final five sessions of exposure to the listed condition.

	Incorrect responses		Correct responses			
Condition	Green on left key	Green on right key	Green on left key	Green on right key	Food deliveries on red trials	Total food deliveries
1	43	6	68	28	45	86
1	20	12	93	91	80	152
1	21	25	111	105	81	155
1	11	21	95	88	82	154
1	21	11	113	74	81	155
1	14	36	77	71	81	155
2	24	2	72	49	61	118
2	3	40	66	121	77	155
2	50	31	98	94	78	155
2	7	40	68	124	79	155
2	24	17	103	83	78	154
2	7	85	50	117	78	154
3	24	0	59	44	52	107
3	21	16	93	64	77	155
3	18	25	98	62	78	155
3	2	13	78	72	78	154
3	3	2	53	54	60	117
3	4	16	84	84	78	155
4	32	4	86	68	61	126
4	35	15	112	92	78	154
4	36	17	124	99	79	154
4	18	19	116	85	78	153
4	17	5	99	84	77	155
4	6	39	79	105	76	154
5	55	3	122	61	75	154
5	39	24	98	96	75	155
5	28	24	90	99	79	154
5	15	58	90	122	80	155
5	21	6	105	88	80	155
5	25	66	73	131	75	155
6	17	8	55	50	52	98
6	6	22	73	104	77	155
6	1	17	65	107	79	154
6	8	23	86	92	77	155
6	2	0	75	81	78	155
6	5	23	85	87	77	155
7	35	3	100	55	75	155
7	6	23	67	121	75	155
7	21	8	95	85	80	155
7	6	31	80	97	80	155
7	3	1	81	73	79	155
7	18	44	49	109	76	155
8	6	0	69	53	73	150
8	3	2	72	84	76	155
8	7	4	85	87	80	155
8	1	8	69	79	80	155
8	1	2	72	74	79	155
8	2	6	73	79	75	155
9	9	5	60	62	57	112
9	3	1	85	79	76	155
9	2	2	107	82	79	155
9	1	6	76	90	79	155
9	1	2	78	64	79	155
9	9	1	71	71	75	155
10	10	38	62	89	70	143
10	6	19	95	108	75	155
10	10	20	95	88	80	155
10	4	16	91	119	80	155
10	7	4	95	78	80	155
10	14	11	94	81	74	154
11	137	34	148	42	74	153
11	21	102	67	139	75	155
11	27	60	83	153	80	154
11	23	118	43	168	80	154
11	92	18	142	84	79	154
11	41	122	64	158	80	155
12	127	30	134	31	75	155
12	39	57	102	96	75	155
12	12	24	109	118	79	155
12	6	56	52	126	78	153
12	27	15	107	88	80	155
12	115	40	128	63	76	155
13	60	33	90	71	75	155
13	9	57	67	101	75	155
13	21	12	87	94	79	155
13	17	25	76	90	80	155
13	5	2	110	121	80	155
13	53	53	88	82	76	155