AROUSAL, CHANGEOVER RESPONSES, AND PREFERENCE IN CONCURRENT SCHEDULES

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Pigeons were trained on multiple schedules that provided concurrent reinforcement in each of two components. In Experiment 1, one component consisted of a variable-interval (VI) 40-s schedule presented with a VI 20-s schedule, and the other a VI 40-s schedule presented with a VI 80-s schedule. After extended training, probe tests measured preference between the stimuli associated with the two 40-s schedules. Probe tests replicated the results of Belke (1992) that showed preference for the 40-s schedule that had been paired with the 80-s schedule. In a second condition, the overall reinforcer rate provided by the two components was equated by adding a signaled VI schedule to the component with the lower reinforcer rate. Probe results were unchanged. In Experiment 2, pigeons were trained on alternating concurrent VI 30-s VI 60-s schedules. One schedule provided 2-s access to food and the other provided 6-s access. The larger reinforcer magnitude produced higher response rates and was preferred on probe trials. Rate of changeover responding, however, did not differ as a function of reinforcer magnitude. The present results demonstrate that preference on probe trials is not a simple reflection of the pattern of changeover behavior established during training.

Key words: arousal, concurrent schedules, changeover behavior, reinforcer duration, preference, key peck, pigeons

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Extensive study of choice behavior has shown the broad applicability of the matching law (Herrnstein, 1961, 1970). Regardless of the species studied, the type of reinforcer, and so forth, choice behavior is generally distributed proportionally to the reinforcer rate available on the choice alternatives (for reviews, see Davison & McCarthy, 1988; Williams, 1988). Despite its success in describing choice behavior, however, the mechanisms underlying the matching law continue to be inadequately understood.

One set of explanations focuses on relative time to reinforcers associated with each choice alternative (e.g., Gibbon, Church, Fairhurst, & Kacelnik, 1988; Mark & Gallistel, 1994). These accounts assume that the inter-reinforcer intervals associated with each alternative guide behavior allocation. For example, scalar expectancy theory (SET) views matching as the result of the memory of the individual delays associated with each schedule of reinforcement (Gallistel & Gibbon,

2000; Gibbon et al., 1988). Choice decisions are governed by organisms sampling delay values from their memories of the interreinforcement delays associated with each alternative.

Belke (1992), however, provided a strong challenge to the SET account. Belke trained pigeons on two alternating concurrent choice schedules. In one, a variable interval (VI) 20-s schedule of reinforcement was presented concurrently with a VI 40-s schedule. In the other, an equivalent VI 40-s schedule was presented concurrently with a VI 80-s schedule. When performance became stable, Belke presented transfer tests in which the two VI 40-s schedules were concurrently presented during extinction. Subjects strongly preferred the VI 40-s component previously paired with the VI 80-s component. Because the overall set of memories for delays would be the same for the two VI 40-s components in Belke's study, SET predicts, on average, indifference between the two components during transfer tests and therefore does not account for the strong preference observed.

To rectify this inadequacy, Gibbon (1995) modified SET to include assumptions about the rates of changeover between components. He noted that Myerson and Miezin (1980) showed that the rate of changing between components of a concurrent schedule

is monotonically related to the total reinforcer rate (summed over all schedule components), an effect they ascribed to *arousal level*. A similar identification of arousal with total reinforcer rate is postulated in Killeen's (1975) model of choice behavior. In Gibbon's analysis, the arousal level determines the rate of decision-making related to staying or leaving a given choice option, even though the actual decisions are determined by the set of interreinforcer intervals associated with each alternative. For example, the higher overall reinforcer rate in the concurrent VI 40-s VI 20-s schedule in Belke's (1992) study should engender higher rates of switching out of the 40-s schedule, compared to the 40-s schedule paired with the 80-s schedule. If differential changeover rates are in fact established during training, and subjects generalize these rates to probe trials, Gibbon's analysis predicts strong preference for the 40-s component previously paired with the 80-s schedule. That is, the 40-s component from the richer (20 vs. 40) context would result in shorter stay times compared to the 40-s component from the leaner (40 vs. 80) context. With Gibbon's modification, then, SET becomes consistent with Belke's results.

In support of his "arousal" analysis, Gibbon (1995) also presented probe tests in which the VI 20-s alternative was pitted against the VI 40-s alternative from the concurrent VI 40-s VI 80-s pair. Here, preference was in favor of the VI 40-s component, even though the schedule values would predict exactly the opposite result. Gibbon compared the distribution of average stay times for each component during training and probe testing and found similar patterns of responding. This suggests that perhaps the changeover pattern, rather than the schedule value, may be the dominant determinant of preference on the probe trials.

The present studies tested Gibbon's (1995) explanation of Belke's (1992) probe test results. In Experiment 1, we first replicated Belke's procedure and then retrained subjects in a procedure in which the overall reinforcer rates for the two choice situations were equated. If preference in probe tests similar to those used by Belke was impacted by differential changeover rates produced by the different reinforcer rates, equating the overall training reinforcer rates for the two schedules

should attenuate preference during probe trials. Experiment 2 provided a further test of Gibbon's arousal explanation by manipulating the reinforcer magnitudes in different components of a multiple schedule. If the difference in the amount of food alters the level of arousal, the component in which the amount of food is greater should produce a higher level of arousal that in turn should produce higher rates of changeover responses.

EXPERIMENT 1

METHOD

Subjects

The subjects were 8 adult White Carneau pigeons with prior experimental histories. They were maintained at approximately 85% of their free-feeding weights by grain obtained during experimental sessions and postsession feedings when necessary. The pigeons were housed in individual cages under a 12:12 hr light/dark cycle, with water and grit freely available.

Apparatus

Eight experimental chambers (approximately 360 mm wide, 320 mm long, and 350 mm high) were used. Three translucent response keys, 25 mm in diameter, were mounted on the front intelligence panel 260 mm above the floor and 72.5 mm apart. Each key required a force of approximately 0.15 N to operate and could be illuminated from the rear by standard IEE 28-V 12-stimulus projectors. A 28-V 1-W miniature lamp, located 87.5 mm above the center response key, provided general chamber illumination. Directly below the center key and 9.5 cm above the floor was an opening (57 mm high by 50 mm wide) that provided access to a solenoid-operated grain hopper. When activated, the hopper remained raised for 3 s, during which time it was illuminated from above with white light by a 28-V 1-W miniature lamp. A speaker mounted above the center of the ceiling provided continuous white noise throughout the experimental sessions. IBM®-compatible computers and a custom-built interface controlled experimental events. These were programmed using Borland's Turbo Pascal®, and were located in an adjacent room.

Table 1

Stimulus assignments and schedules of reinforcement in experiment 1.

	Component A		Component B	
Group	Center key white	Right key red	Left key green	Center key yellow
1	VI 20 s	VI 40 s (a)	VI 40 s (b)	VI 80 s
2	VI 80 s	Vi 40 s (b)	VI 40 s (a)	VI 20 s

Procedure

Baseline training. The general procedure was a systematic replication of Belke (1992) that consisted of a concurrent VI 20-s VI 40-s schedule of reinforcement alternated with a concurrent VI 40-s VI 80-s schedule. Pigeons 276, 277, 178, and 118 were assigned to Group 1, and Pigeons 278, 279, 114, and 9 were assigned to Group 2. Each group was exposed to a multiple schedule comprised of concurrent VI components. The stimulus colors used were the same as in Belke, although the response-key locations were different because our chambers had only three keys available. The stimulus assignments and response-key locations are outlined in Table 1. Each concurrent schedule was presented for 60 s and was followed by 10-s blackouts. The VI values were selected from a Fleshler and Hoffman (1962) progression of 10 intervals. Interval values for each trial were randomly selected with the limitation that all values were used before they once again became available for selection. As in Belke's study, a 1-s changeover delay (COD) was used to reduce the impact of reinforcement on switching behavior.

The first component presented in each session was selected randomly, and sessions were terminated after each component was presented 15 times. Training continued for a minimum of 15 sessions, after which both time and response proportions for each component were assessed daily for stability. The last nine sessions were divided into blocks of three consecutive sessions and the means of each block were computed. Preference was considered stable when each block mean did not differ by more than .05 and consecutive block means showed neither an upward nor a downward trend. The training phase continued until response and time proportions for both components simultaneously met the

stability criteria, or until a maximum of 57 sessions was reached.

Test sessions. After completion of training, a series of four transfer test sessions was conducted, with two baseline training sessions between each test session. Test sessions consisted of regular training trials interspersed with probe trials. A probe trial consisted of the simultaneous illumination of the two stimuli assigned to the VI 40-s schedules. The probe stimuli were presented for 60 s, during which responses were not reinforced. One probe trial was interspersed within each block of six regular training trials, with the placement of the probe trial randomly determined. Reinforcer delivery continued according to the usual schedules for the training trials.

Signaled extra food. Following the baseline and test phases, subjects received additional training on the baseline procedure that was modified to approximately equate the reinforcer rates delivered in the two components of the multiple schedule. This was accomplished by providing a signaled VI 26.6-s schedule of reinforcement on the unused side key during the VI 40-s VI 80-s concurrent schedule. A vertical line was illuminated on the side key only when a reinforcer was available on the VI 26.6-s schedule. A single peck to the key darkened it and provided a reinforcer. Training was continued until the stability criterion was reached, after which test sessions were conducted as described for the baseline condition.

RESULTS

Baseline Training

Figure 1 shows the response and time allocation results for each subject in the baseline condition. The top panel shows data from the VI 40-s versus VI 20-s component of the multiple schedule; the bottom panel shows data from the VI 40-s versus VI 80-s component. Pigeon 9 was dropped from the study after 24 baseline sessions because it never pecked one of the VI 40-s components. The mean response and time allocation proportions for the VI 40-s schedule paired with the VI 20-s schedule were .24 and .17, respectively. The mean response and time allocation proportions for the VI 40-s schedule paired with the VI 80-s schedule were .79 and .78, respectively. In both cases, these preference
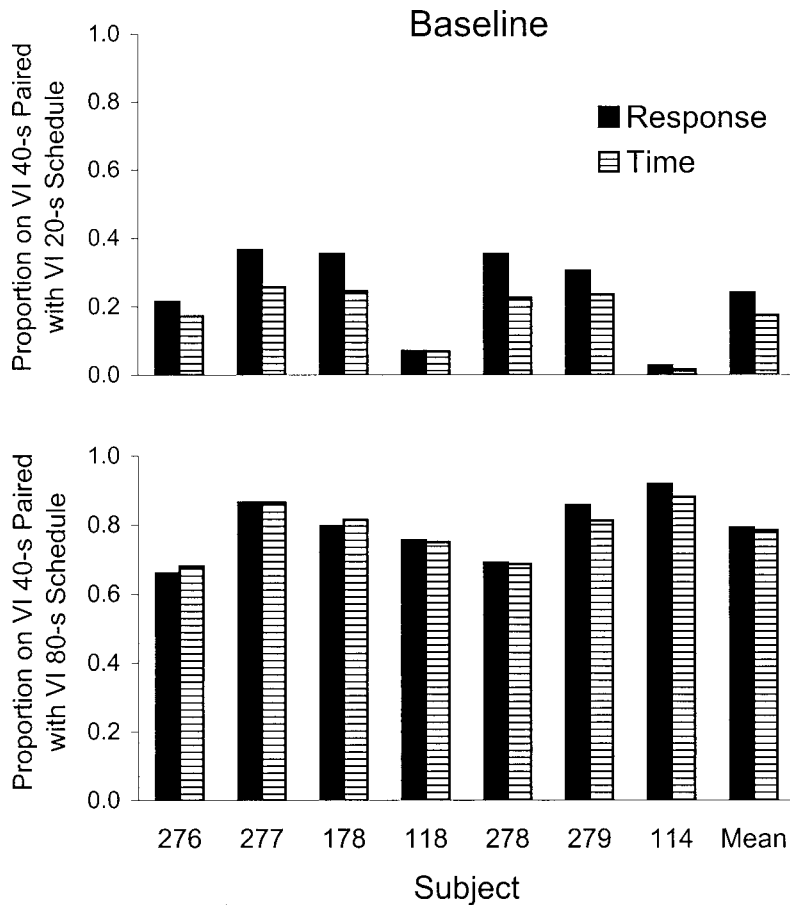
Fig. 1. Results from the last nine sessions for each pigeon in the baseline condition of Experiment 1. The top graph shows the proportion of responses and time to the VI 40-s component paired with the VI 20-s component. The bottom graph shows the proportion of responses and time to the VI 40-s component paired with the VI 80-s component.

levels are more extreme than is predicted by matching.

Table 2 shows individual subjects' response rates in each component presented during training, the number of training sessions, as well as the results of the probe trials. As expected, all subjects responded during the baseline training at higher rates to the VI 40-s schedule paired with the VI 80-s schedule than to the VI 40-s component paired with the VI 20-s schedule (101 vs. 28 mean responses per minute). Total response rates summed over both choice alternatives were slightly greater for the concurrent VI 40-s VI 80-s (127 vs. 114), but this difference was not statistically reliable at the $p < .05$ level that was used for all statistical tests.

During probe tests in which both VI 40-s stimuli were presented, 6 of 7 subjects responded more to the VI 40-s stimulus previously paired with the VI 80-s schedule (.69 mean response proportion). Despite the aberrant behavior of Pigeon 178, this choice proportion was reliably different from .50; $t(6) = 2.67$, $p < .05$. Time allocation was less extreme: Four of the 7 subjects spent more time responding to the VI 40-s stimulus previously paired with the VI 80-s schedule (.55 mean time proportion). The time proportion was not reliably different from .50 ($t < 1.0$).

Signaled Extra Food

The signaled extra food condition was used to equate the overall reinforcer rates available in the two components. Figure 2 compares the mean number of reinforcers per session

Table 2

Results of the baseline condition of experiment 1.

| Subject | Number of sessions | Responses per minute | | | | Probe preferences for VI 40 s (b) | |
		VI 20 s	VI 40 s (a)	VI 40 s (b)	VI 80 s	Response	Time
276	57	120	33	101	52	.71	.55
277	25	60	35	99	16	.62	.69
178	57	47	26	93	24	.31	.34
118	16	93	7	54	15	.82	.77
278	43	99	54	96	43	.69	.65
279	57	84	37	114	19	.83	.40
114	15	102	3	146	12	.85	.43
Mean	39	86	28	101	26	.69	.55

in each component in each condition. On average, the difference between components in terms of mean total reinforcers per session was reduced from 14 in the baseline condition to only three in the signaled extra food condition.

Figure 3 shows the response and time allocation results for each subject in the signaled extra food condition. The top panel shows data from the VI 40-s versus VI 20-s component of the multiple schedule, and the bottom panel shows data from the VI 40-s versus VI 80-s component. The mean response and time allocation proportions for the VI 40-s schedule paired with the VI 20-s schedule were .28 and .20, respectively. The mean response and time allocation proportions for the VI 40-s schedule paired with the VI 80-s schedule were .74 and .73, respectively. Thus preference levels were similar, but slightly less
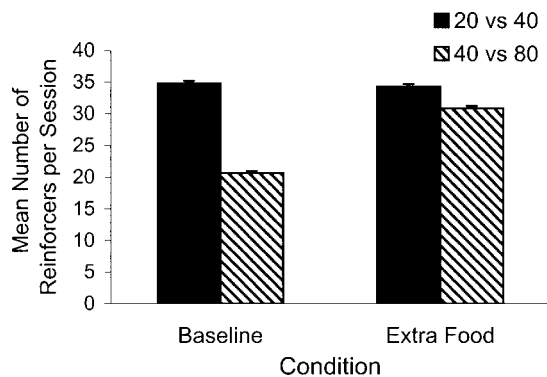

Fig. 2. Mean number of reinforcers per session for each component of the multiple schedule from the last nine sessions of the baseline and extra food conditions. Error bars indicate standard error values.

extreme, than those observed during the baseline condition.

Table 3 shows individual subjects' response rates in each component, the number of sessions, and probe results. Adding a signaled VI 26.6 s to the concurrent VI 40-s VI 80-s component had little effect on behavior in the concurrent VI 20-s VI 40-s component, but resulted in a marked reduction in response rate in the concurrent VI 40-s VI 80-s component (from 127 to 80 responses per minute). This reduction was statistically reliable, $t(6) = 5.76$, $p < .05$. All subjects maintained higher rates to the VI 40 component paired with the VI 80-s schedule (i.e., VI 40b) than to the VI 40 component paired with the VI 20-s schedule (i.e., VI 40a), but the ratio of response rates was greatly reduced in the signaled extra food condition. The mean ratio of response rates for the two VI 40-s schedules (40a:40b) during baseline training was approximately 1:4. During the signaled extra food condition, this ratio was reduced to about 1:2. Probe tests results, however, were similar to baseline results: Six of 7 subjects responded more to the VI 40-s stimulus previously paired with the VI 80-s schedule (.71 mean response proportion), which was reliably different from the .50 indifference level; $t(6) = 3.14$, $p < .05$. As observed during baseline probe tests, time allocation was less extreme: Five of the 7 subjects spent more time responding to the VI 40-s stimulus previously paired with the VI 80-s stimulus (.54 mean time proportion that, again, was not statistically reliable).

Changeover Behavior

Figure 4 shows the changeover rates in each component, averaged over the last nine
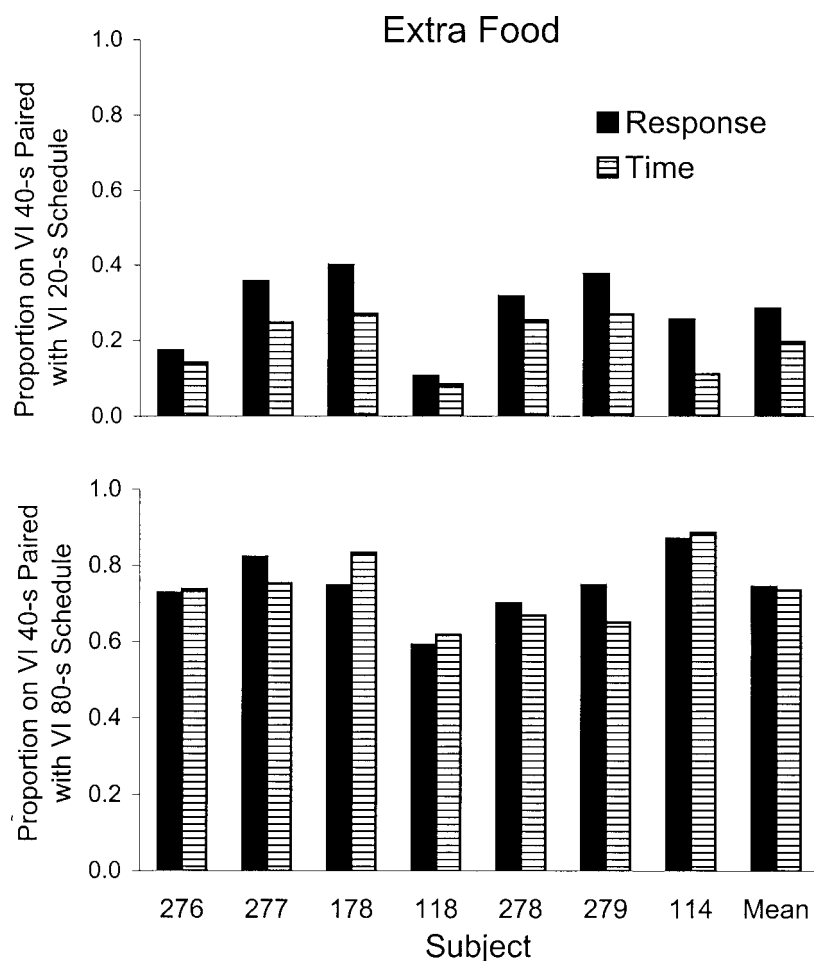
Fig. 3.   Results for the last nine sessions for each pigeon in the extra food condition of Experiment 1. The top graph shows the proportion of responses and time to the VI 40-s component paired with the VI 20-s component. The bottom graph shows the proportion of responses and time to the VI 40-s component paired with the VI 80-s component. The extra food condition differed from the baseline condition in that during the VI 40-s versus VI 80-s component of the multiple schedule, a signaled VI 26.5-s schedule of reinforcement was operative.

Table 3

Results of the signaled extra food condition of Experiment 1.

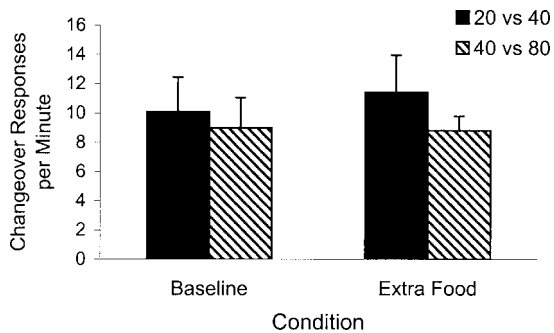| Subject	Number of sessions	Responses per minute				Probe preference for VI 40 s (b)	
		VI 20 s	VI 40 s (a)	VI 40 s (b)	VI 80 s	Response	Time
276	19	123	26	66	25	.92	.95
277	18	59	33	71	15	.70	.63
178	40	58	39	48	16	.50	.55
118	57	90	11	37	26	.46	.33
278	57	105	49	54	23	.87	.21
279	38	81	49	60	20	.77	.55
114	38	86	30	83	12	.72	.59
Mean	31	86	34	60	20	.71	.54

Fig. 4. Mean number of changeover responses per minute, for each component of the multiple schedule, from the last nine sessions of the baseline and extra food conditions. Error bars indicate standard error values.

sessions of the baseline and extra food conditions. Baseline rates averaged 10 and 9 changeovers per minute during the concurrent VI 20-s VI 40-s and concurrent VI 40-s VI 80-s components, respectively. When the signaled VI schedule was added, the average changeover rate in the concurrent VI 20-s VI 40-s component increased slightly to 11 changeovers per minute, but remained at 9 changeovers per minute in the VI 40-s VI 80-s component in which the signaled extra food was added. Due to the considerable variability across subjects, this difference was not statistically reliable. Nor was there any relation between changeover rates during training and preference on probe trials. The ratio of changeover rates for each 40-s component during training (40a:40b) was not correlated with the degree of preference for the 40b component during probe trials ($r = -.01$ for the baseline condition and $r = .07$ for the extra food condition).

DISCUSSION

Experiment 1 successfully replicated Belke's (1992) pattern of results: Strong preference occurred in the probe trials for the VI 40-s stimulus paired with the VI 80-s schedule (i.e., 40b). According to Gibbon's (1995) analysis, the enhanced arousal in the VI 20-s versus 40-s concurrent schedules produced by the higher total reinforcers causes an increased rate of changeover responding. This assumption was not supported in the baseline condition, as changeover rates did not vary consistently in the two choice situations. The second condition of Experiment 1 equated

the overall reinforcer rates in the two choice situations. If Gibbon's analysis of Belke's results is correct, the manipulation should affect preference during 40a versus 40b probe trials. Although the signaled extra food during the 40b versus 80 concurrent schedule significantly affected response rate to the 40b component, it did not increase the rate of changeover responses, nor did it affect preference during the 40a versus 40b probe trials. The present results thus demonstrate that replication of Belke's probe test results is not dependent on a differential pattern of changeover behavior established during training. Although transfer of the changeover pattern from training to the probe testing could possibly explain the results reported by Gibbon, Williams and Bell (1999) reported that differential changeover rates produced by differential changeover delays had no effect on preference during the probe trials, which was determined primarily by the schedule values during training.

The present data from the baseline condition appear to differ from those reported by Gibbon (1995) with respect to the effect of overall reinforcer rate on changeover rate. Gibbon did not report the changeover rate per se, but instead reported the distribution of dwell times for each choice alternative. When these are converted to the average interchangeover times, his obtained changeover rates were approximately twice as great for the concurrent VI 20 s VI 40 s than for the concurrent VI 40 s VI 80 s. One possible reason for the discrepancy is that Gibbon used a Findley (1958) changeover-key procedure whereas the present study used the standard two-key choice procedure. Nevertheless, the failure to replicate his changeover-rate results during baseline training does not undermine the important fact that we successfully replicated Belke's (1992) probe test results. If, as Gibbon suggested, differential changeover rate is an important determinant of preference during probe tests, then it should have affected the probe test results between the two VI 40-s components. Instead, we found preference levels similar to those observed by Belke and Gibbon.

It is noteworthy that previous results regarding the relation between total response rate in concurrent schedules and the changeover rate between the choice alternatives are

inconsistent. Although some reports suggest both measures generally increase with total reinforcer rate (e.g., Myerson & Miezin, 1980), others either fail to find consistent relations or observe opposite effects. For example, Findley (1958) reported that changeover rate did not vary consistently with changes in overall reinforcer rate, but found that response rates generally did show a consistent relation with overall reinforcer rates. Elliffe and Alsop (1996) presented concurrent schedules in a series of conditions in which the overall reinforcer rate was varied from 0.25 to 10 reinforcers per minute. In conditions in which obtained reinforcer rates were less than two reinforcers per minute, they report average changeover rates of 2.5 to 3.0 per minute. In conditions in which obtained reinforcers were greater than three reinforcers per minute, mean changeover rates increased slightly to between three and four changeovers per minute (Figure 4, p. 453). An analysis of the data in their appendix, however, suggests that the mean number of changeovers per session decreased consistently with increases in the scheduled rate of reinforcers. Because Elliffe and Alsop did not report mean session durations, we were unable to calculate the relation between the scheduled rate of reinforcers and changeovers per minute.

EXPERIMENT 2

Experiment 1 equated the overall reinforcer rates in Belke's (1992) procedure without affecting preference levels during the probe trials. Experiment 2 provided a more direct test of the relation between arousal levels and changeover patterns by creating differential arousal levels in two choice situations by using different reinforcer magnitudes. Killeen (1985) has shown that reinforcer magnitude is similar to reinforcer rate in its effects on arousal level in that both increase arousal level in a monotonic fashion over a large range of values. In Experiment 2, one component of a multiple schedule consisted of a concurrent schedule that provided 2-s access to food, whereas the other component consisted of a concurrent schedule that provided 6-s access to food. McLean and Blampied (2001) found consistently higher response rates when concurrent VI schedules provided 6-s

instead of 2-s access to food. Assuming that the larger reinforcer magnitude produces higher arousal levels, Gibbon's (1995) analysis implies that the concurrent schedule with a larger reinforcer magnitude should have higher rates of switching between components. Further, if differential changeover rates are the basis of Belke's probe results, then probe tests between response alternatives that have equal VI schedule values but unequal reinforcer magnitudes should favor the alternative trained with the smaller amount. This prediction is similar to Gibbon's prediction of preference for the VI 40 s from the concurrent VI 40 s VI 80 s over the VI 20 s from the concurrent VI 20 s VI 40 s, and thus represents a powerful test of the generality of his arousal analysis.

METHOD

Subjects

The subjects were 6 adult homing pigeons with experience in one previous choice experiment using VI schedules with different reinforcer magnitudes. They were maintained at approximately 85% of their free-feeding weights by mixed grain obtained during experimental sessions and postsession feedings when necessary. The pigeons were housed in individual cages under a 12:12 hr light/dark cycle, with water and grit freely available.

Apparatus

The apparatus described in Experiment 1 was used, except that only three of the four experimental chambers were used.

Procedure

The general procedure consisted of two pairs of concurrent VI 30-s VI 60-s schedules of reinforcement. During one pair of schedules (Components A-2 vs. B-2), the reinforcer consisted of 2-s access to mixed grain, and during the other pair of schedules (components A-6 vs. B-6) the reinforcer consisted of 6-s access to mixed grain. The VI values were selected from a Fleshler and Hoffman (1962) progression of 10 intervals. Interval values for each trial were randomly selected, with the limitation that all values were used before they once again became available for selec-

tion. Pigeons 571, 131, and 582 were assigned to Group 1, and Pigeons 593, 595, and 158 were assigned to Group 2. Group 1 stimulus assignments were white, red, green, and blue keylights for stimuli A-2, B-2, A-6, and B-6, respectively. Group 2 stimulus assignments were blue, green, red, and white keylights for stimuli A-2, B-2, A-6, and B-6, respectively. Each stimulus was presented equally often on the left and right keys so that for every four trials of each schedule type, each component was presented on each side twice.

The first component presented in each session was selected randomly, and the two concurrent schedules subsequently alternated. Each concurrent schedule was presented for 60 s and was followed by 10-s blackout components. Sessions were terminated after each component was presented for 16 trials. Training continued until each subject met the stability criterion described in Experiment 1 or reached a maximum of 53 sessions.

Test sessions. After completion of training, a transfer test session was presented. Four test sessions were conducted, with each test session separated from the next by two baseline sessions. Test sessions consisted of regular training trials interspersed with probe trials. The probe stimuli were presented for 60 s, during which no responses were reinforced. Probe trials were presented in random order and consisted of two each of the following types: A-2 versus A-6, A-2 versus B-6, B-2 versus A-6, and B-2 versus B-6. One probe trial was interspersed within each block of four regular training trials, with the placement of the probe trial randomly determined. Reinforcer delivery continued according to the usual schedules for the training trials.

RESULTS

Table 4 shows the results of the last nine sessions of training for each subject. Overall, subjects developed a slightly higher level of preference for the VI 30-s schedules than predicted by matching (.72 and .74 choice proportions in the 2-s and 6-s food components, respectively). The summed rates of responding to the two 6-s food components were higher than the summed rates of responding to the two 2-s food components (50 vs. 38 responses per minute), and this difference was statistically reliable, $t(5) = 3.83$, $p < .05$. Thus the response rate measure demonstrates that the larger reinforcer magnitude functioned as a more effective reinforcer.

The effect of differential reinforcer magnitudes was not as consistent with respect to changeover behavior. The last two columns of Table 4 compare the mean number of changeover responses per session for the 2-s and 6-s food alternatives. The 6-s food alternatives produced a slightly higher mean rate of changeover behavior (68 and 79 mean changeovers per session for the 2-s and 6-s food alternatives, respectively). Only 4 subjects showed this pattern, however, and 2 showed the reverse pattern. The difference between the changeover rates with 2-s and 6-s reinforcers was not statistically significant, $t(5) = .98$, $p = .37$.

Probe Tests

Figure 5 shows the results for individual subjects for the probe trials. The choice alternatives available on the probe trials always differed in terms of reinforcer magnitude but could either have the same VI schedules or different VI schedules. The top panel of Fig-

Table 4

Results from the last nine sessions of Experiment 2.

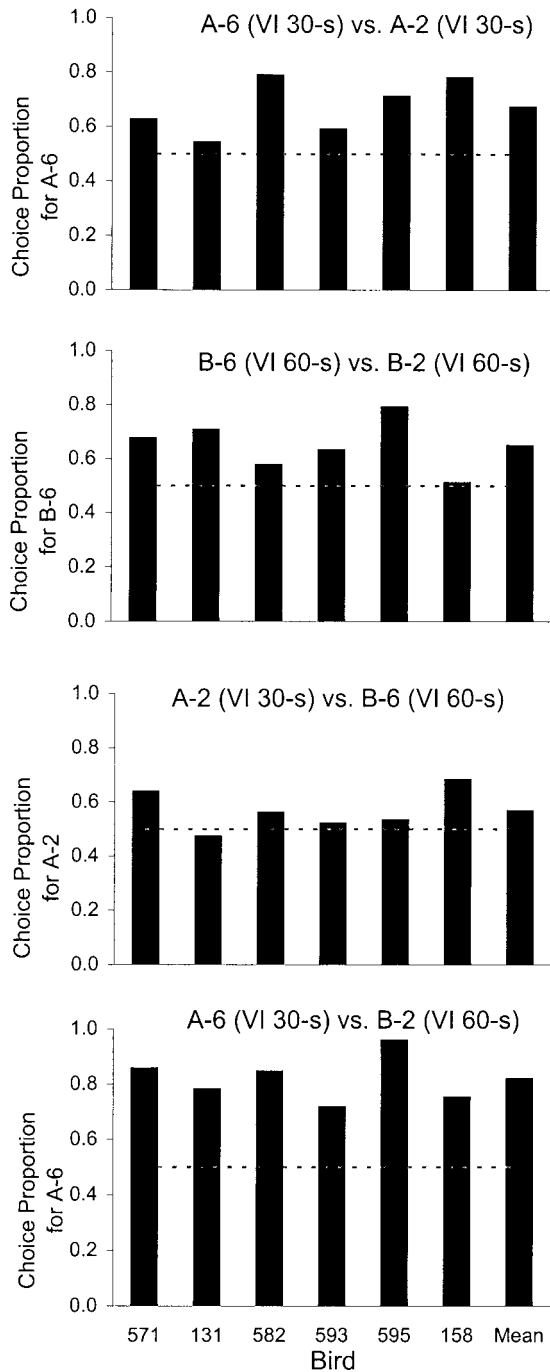| Subject	Number of sessions	Responses per minute				Preference for VI-30 s		Changeover responses	
		A-2	B-2	A-6	B-6	2-s Food	6-s Food	2-s Food	6-s Food
571	34	29	7	32	12	0.80	0.72	34	88
131	40	27	16	35	21	0.63	0.63	82	100
582	53	28	11	37	8	0.72	0.81	80	63
593	39	28	8	36	8	0.77	0.81	74	55
595	51	13	5	25	9	0.70	0.71	28	32
158	38	35	17	59	22	0.68	0.73	110	137
Mean	43	27	11	37	13	0.72	0.74	68	79

Fig. 5. Individual subject probe test results from Experiment 2. The top two panels show data from probe trials involving components that differed in the reinforcer magnitude provided during training. The bottom two panels show data from probe trials involving components for which both the VI schedules and the reinforcer magnitudes differed during training.

ure 5 shows the probe results when the alternatives were both VI 30-s schedules. For all subjects, preference was in favor of the alternative trained with the larger reinforcer magnitude (mean preference = .67). Preference was reliably different from .50, t (5) = 4.13, $p < .05$. The second panel shows the probe results when both alternatives had been trained with the VI 60-s schedule. All subjects again preferred the alternative with the 6-s reinforcer (mean preference = .65), although Pigeon 158 was close to indifference. Preference, however, again differed reliably from .50, t (5) = 3.71, $p < .05$. The third panel of Figure 5 shows the results when both the schedule values and reinforcer magnitudes were unequal, but with the two variables working in opposition. Here there was a slight mean preference for the VI 30-s alternative (mean choice proportion = .57), and this effect was not statistically reliable, $p > .05$. The fourth panel of Figure 5 shows the results when the amount and schedule values were consistent rather than in opposition (i.e., the VI 30-s schedule with the larger reinforcer was paired with the VI 60-s schedule with the smaller reinforcer). Here the preference values were the largest of the four types of probes (mean preference = .82), and again differed reliably from .50, t (5) = 8.94, $p < .05$.

Comparison of the four types of probes suggests that reinforcer rate and magnitude were approximately additive in their effects on the probe preferences, with the effect of reinforcer rate being slightly larger.

DISCUSSION

Experiment 2 demonstrated that 6-s food delivery was a more effective reinforcer than the 2-s food delivery, both in terms of producing higher response rates and the pattern of preference on the probe trials. Presumably, therefore, the larger reinforcer magnitude also produced a higher level of arousal. According to Gibbon's (1995) analysis, change-over rates should have been higher with the 6-s reinforcers, and as a consequence preference should have been in favor of the probe alternative associated with the smaller reinforcer magnitude. The opposite result was obtained, as the preference pattern in probe trials was controlled in a similar fashion by both magnitude and rate of reinforcers.

Although arousal appears to have been effectively manipulated in Experiment 2 in terms of the effect of reinforcer magnitude on response rate and preference, the larger reinforcer magnitude did not produce a higher changeover rate. Although there was a numerically greater mean number of changeovers with the 6-s reinforcers, it did not approach statistical reliability due to the high level of intersubject variability. Yet all subjects showed a consistent preference for the larger reinforcer during the probe trials. Averaged over all four types of probe trials, the mean preference for the 6-s reinforcer component was .64, and there was no discernible relation between the degree of that preference and the changeover rates during the baseline performance. This seems to suggest that changeover rates are not consistently affected in the same way as other measures of behavior (e.g., response rate) when variables purported to correspond to the construct arousal are manipulated.

The present results thus demonstrate that preference on probe trials is not simply a reflection of the pattern of changeover behavior established during training. Although transfer of the changeover pattern from training to the probe testing could possibly explain the results reported by Gibbon (1995), both the present results and those of Williams and Bell (1999) show that the schedule values, per se, seem to be the dominant determinant of preference during the probe trials. In the latter study, differential changeover rates were established by using either short or long CODs during training, with the result that the changeover rates were approximately twice as great with the shorter values. Nevertheless, the COD value had no effect on performance during the probe trials that was entirely determined by the VI values associated with the individual choice alternatives. The results of Williams and Royalty (1989) are similarly consistent with this view.

The problem thus posed is why the schedule values did not determine the pattern of preference obtained by Belke (1992). One hypothesis is that the schedules, per se, are the primary determinants of preference, but the changeover pattern established during training becomes influential when the schedule values are equal. Gibbon's (1995) finding of preference for the VI 40 from the concur-

rent VI 40 s VI 80 s over the VI 20 from the concurrent VI 20 s VI 40 s, if reliable, shows this cannot be generally true. The issue, then, is how to predict when the changeover pattern versus the schedule value will be dominant, or whether an alternative formulation of multiple schedule performance (e.g., McLean & White, 1983) can account for Belke and Gibbon's results.

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