TWO-KEY CONCURRENT PACED VARIABLE-INTERVAL PACED VARIABLE-INTERVAL SCHEDULES OF REINFORCEMENT¹

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Nine pigeons were used in two experiments in which a response was reinforced if a variable-interval schedule had assigned a reinforcement and if the response terminated an interresponse time within a certain interval, or class, of interresponse times. One such class was scheduled on one key, and a second class was scheduled on a second key. The procedure was, therefore, a two-key concurrent paced variable-interval paced variable-interval schedule. In Exp. I, the lengths of the two reinforced interresponse times were varied. The relative frequency of responding on a key approximately equalled the relative reciprocal of the length of the interresponse time reinforced on that key. In Exp. II, the relative frequency and relative magnitude of reinforcement were varied. The relative frequency of responding on the key for which the shorter interresponse time was reinforced was a monotonically increasing, negatively accelerated function of the relative frequency of reinforcement on that key. The relative frequency of responding depended on the relative magnitude of reinforcement in approximately the same way as it depended on the relative frequency of reinforcement. The relative frequency of responding on the key for which the shorter interresponse time was reinforced depended on the lengths of the two reinforced interresponse times and on the relative frequency and relative magnitude of reinforcement in the same way as the relative frequency of the shorter interresponse time depended on these variables in previous one-key concurrent schedules of reinforcement for two interresponse times.

Two recent studies have shown that when two interresponse times are concurrently reinforced the relative frequency of the shorter interresponse time is a monotonically increasing, negatively accelerated function of both its relative frequency of reinforcement and its relative magnitude of reinforcement (Shimp, 1968; Staddon, 1968). Furthermore, it has been noted that the relative frequency of one of two reinforced interresponse times equals the relative reciprocal of its length when the relative frequency and relative magnitude of reinforcement both equal 0.50 (Shimp, 1969, 1970).

These functions were obtained from schedules in which both interresponse times were concurrently reinforced on a single key. In the present study, two keys were used: one interresponse time was reinforced on one key and a second interresponse time was reinforced on a second key. An attempt was made to deter-

mine how the functions obtained with this two-key procedure are related to the functions obtained with the previous one-key procedures.

In Exp. I, the lengths of the two reinforced interresponse times were varied as in Shimp's (1969) experiment. In Exp. II, either the relative frequency or the relative magnitude of reinforcement for an interresponse time was varied as in the previous one-key experiments (Shimp, 1968; Staddon, 1968). There were two groups of pigeons in Exp. II. The lengths of the reinforced interresponse times for one group were the same as those used by Shimp; the lengths of the reinforced interresponse times for the second group were the same as those used by Staddon.

GENERAL METHOD

Apparatus

The left and right keys in a Lehigh Valley Electronics three-key pigeon chamber (Model 1519B) were used. Electromechanical relay equipment scheduled reinforcements and recorded interresponse times.

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Procedure

The reinforcement schedule was a two-key concurrent paced variable interval (VI) paced variable interval (VI) with one interresponse time reinforced on one key and the second interresponse time reinforced on the second key (Ferster and Skinner, 1957; Revusky, 1963; Shimp, 1967). The schedule consisted of three independent parts: a constant reinforcement-per-opportunity VI schedule; a Bernoulli-trials generator; and two pacing contingencies that defined two reinforced interresponse times. Each of these three contingencies is described below in detail.

Pacing contingency. A response could be reinforced only if it terminated a time interval since the last response on the same key that was longer than T_1 sec but shorter than T_2 sec; that is, if it terminated an interresponse time between T_1 and T_2 sec in duration. In addition, the first response after a reinforcement could be reinforced if it terminated a time interval longer than T_1 sec but shorter than T_2 sec, counting from the end of reinforcement, and if it occurred on the same key as the reinforced response. This pacing contingency generally was different for the two keys. As a consequence of this contingency, the first response on a key, *i.e.*, a switching response, was never reinforced; that is, the pacing contingency provided a built-in changeover delay.

VI schedule. The times between successive reinforcements were arranged by a single, constant reinforcement-per-opportunity VI 30-sec schedule of reinforcement (Catania and Reynolds, 1968). This constant probability of reinforcement was 0.1 every 4.3 sec except at long intervals after reinforcement. When the VI tape assigned a reinforcement, the tape stopped until the reinforcement occurred. However, if a bird ever paused for an interval exceeding the longer reinforced interresponse time, the tape started to move again, and the previously assigned reinforcement was cancelled. The purpose of this cancellation was to prevent reinforcement after a long interresponse time followed by one within the pacing limits.

Bernoulli-trials generator. A sequence of Bernoulli trials is one in which, on every trial, there are two possible outcomes, exactly one of which occurs. The probability (π) of an outcome is constant and independent of the out-

come on the preceding trial. In this experiment, each "trial" had as its possible outcome the assignment of the next reinforcement to the left or right key. A "trial" occurred at the end of each reinforcement. This assignment of the next reinforcement either to the left or right key was not affected by the cancellation of reinforcement by long pauses. For example, if a bird paused for a time exceeding the longer of the reinforced interresponse times when reinforcement was assigned, say, to the left key, the VI tape would start to move once again, but the next reinforcement would still be scheduled for a peck on the left key.

This method of assigning reinforcements in a two-key concurrent schedule by a single VI tape and a Bernoulli-trials generator has two advantages over the method in which there are two VI tapes, one for each key. First, with the method used here, the probability that the obtained relative frequency of reinforcement on a key will deviate from the scheduled probability by any given amount is given by the binomial distribution (Feller, 1957). With the alternative method, the probability of such a deviation is not known. Second, with the method used here, the probability of reinforcement on, say, the left key, is independent of where the preceding reinforcement was assigned. With the alternative method, this conditional probability typically is not known and, in any case, the experimenter has little or no control over it.

Other contingencies. The two keys were illuminated by white light except for an approximately 50-millisecond blackout after each response. In addition, the keylights and house-light were darkened during reinforcement, which was access to an illuminated tray of mixed grain. Subjects were run seven days a week and experimental conditions were terminated when the relative frequency of responding on a key plotted against days looked stable for three or four days.

EXPERIMENT I

In Exp. I, the lengths of the two reinforced interresponse times were varied to determine how the relative frequency of responding on a key depended on the relative reciprocal of the length of the reinforced interresponse time on that key.

METHOD

Subjects

Three male homing pigeons were maintained at approximately 80% of their free-feeding weight and had been used in a previous study on the effects of blackouts in concurrent schedules (Herbert, 1970).

Procedure

Table 1 presents the lengths of the two reinforced interresponse times for each experimental condition and the computed relative reciprocal of the length of the interresponse time reinforced on the left key. The reinforced interresponse times were chosen so that the relative reciprocal of the interresponse time on the left key ranged from approximately 0.15 to 0.85. The relative reciprocal of the length of the interresponse time reinforced on the left key equals $(1/t_L)/(1/t_L + 1/t_R)$ where t_L is the lower bound of the reinforced interresponse time on the left key and t_R is the lower bound of the reinforced interresponse time on the right key.

The scheduled probability of reinforcement on the left key (π), remained constant at 0.50. The relative feeder time, (F), equalled $F_1/(F_1 + F_2)$, where F_1 and F_2 were the feeder durations on the left and right keys, respectively. The value of F also remained constant at 0.50. The feeder time was 2.0 sec for both the left and right keys. Sessions lasted 50 min.

RESULTS

Table 2 shows the number of responses and reinforcements on the left and right keys for each of the three birds. The data in the table are from each of the last three sessions of each condition. All of the following computations of relative response frequencies are based on these values. The relative frequency of responding on the left key is the number of responses on the left key divided by the sum of the number of responses on both keys.

Figure 1 shows the relative frequency of responding on the left key as a function of the relative reciprocal of the length of the interresponse time reinforced on that key. Each

Table 1
Experimental Conditions for Experiment I

Condition Number	Number of Sessions	Lower and Upper Bounds of Reinforced IRT on Left Key (sec)	Lower and Upper Bounds of Reinforced IRT on Right Key (sec)	Relative Reciprocal of the Length of the Left IRT
BIRD 1H				
1	15	3.0,8.0	3.0,8.0	0.500
2	10	3.0,4.0	5.25,8.25	0.634
3	10	2.5,3.5	7.5,10.5	0.754
4	10	2.0,3.0	10.0,13.0	0.833
5	10	5.0,8.0	2.0,3.0	0.286
6	11	14.0,17.0	2.0,3.0	0.124
BIRD 2H				
1	15	3.0,8.0	3.0,8.0	0.500
2	10	3.0,4.0	5.25,8.25	0.634
3	10	5.25,8.25	3.0,4.0	0.366
4	11	7.5,10.5	2.5,3.5	0.246
5	19	10.0,13.0	2.0,3.0	0.167
6	9	5.25,8.25	3.0,4.0	0.366
7	25	3.0,4.0	5.25,8.25	0.634
8	9	2.0,3.0	10.0,13.0	0.833
9	14	2.0,3.0	10.0,13.0	0.833
10	10	3.0,4.0	5.25,8.25	0.634
BIRD 3H				
1	15	3.0,8.0	3.0,8.0	0.500
2	10	3.0,4.0	5.25,8.25	0.634
3	10	2.5,3.5	7.5,10.5	0.754
4	9	2.0,3.0	10.0,13.0	0.833
5	20	5.0,8.0	2.0,3.0	0.286
6	19	14.0,17.0	2.0,3.0	0.124
7	9	10.0,13.0	2.0,3.0	0.167
8	10	14.0,17.0	2.0,3.0	0.124

Table 2
Experiment I: Number of Responses and Reinforcements on the Left and Right Keys

Condition Number	Number of Responses on Left Key			Number of Responses on Right Key			Number of Reinforcements on Left Key			Number of Reinforcements on Right Key		
	Bird 1H	Bird 2H	Bird 3H	Bird 1H	Bird 2H	Bird 3H	Bird 1H	Bird 2H	Bird 3H	Bird 1H	Bird 2H	Bird 3H
1	562	411	555	396	500	470	12	24	19	13	10	15
	442	423	537	362	439	399	12	19	19	17	14	12
	401	362	630	657	503	304	11	16	14	18	14	13
2	867	293	228	389	499	225	19	27	14	12	18	13
	894	287	366	390	537	174	14	21	10	10	27	8
	909	247	209	311	573	100	15	19	0	16	21	3
3	655	224	824	249	831	177	10	16	24	13	20	17
	793	198	919	375	826	174	12	15	22	18	20	21
	835	184	711	238	816	159	17	19	13	11	16	16
4	782	178	601	162	1014	88	18	18	9	9	13	7
	683	237	900	176	867	87	12	14	19	7	5	12
	611	260	573	237	954	83	16	13	7	14	8	4
5	315	173	373	1031	628	733	25	19	29	31	11	19
	369	183	377	959	758	780	23	17	29	24	13	22
	320	153	359	1071	765	806	26	13	20	20	13	27
6	158	330	168	1163	604	242	3	27	6	8	21	3
	107	270	207	993	595	280	5	23	6	10	34	6
	109	286	260	1228	571	269	2	35	5	3	24	3
7		480	100		322	502		25	8		20	11
		402	121		348	553		24	6		24	7
		334	158		433	535		20	12		28	13
8		401	160		305	405		5	12		3	11
		417	143		315	485		3	7		5	9
		355	165		318	353		4	4		4	7
9		705			213			10			5	
		875			191			4			3	
		984			167			9			6	
10		481			345			18			20	
		510			295			25			24	
		517			296			22			20

Fig. 1. The relative frequency of responding on the left key as a function of the relative reciprocal of the length of the interresponse time reinforced on that key for each of the last three sessions of each condition. The solid lines represent the matching relationships between the two coordinates, and the dashed lines are least-squares best-fitting straight lines (see text). The triangles represent the values for replications.

panel in the figure corresponds to one of the three birds. The solid lines represent the matching function and the dashed lines are least-squares best-fitting straight lines. The best-fitting lines closely approximate the matching function. However, these lines are based on results from different conditions for the different birds. For Bird 1H, each condition was used in computing the best-fitting line. For Birds 2H and 3H, conditions that were later replicated were not used. For Bird 2H, conditions 2, 3, and 8 were later replicated by conditions 7 and 11, 6, and 10, respectively. For Bird 3H, condition 6 was replicated by condition 9.

Data from replications, which appear in Fig. 1 as triangles, were invariably closer to the matching function than were the data from the corresponding initial conditions. Apparently, in some cases, matching behavior may not be obtained during the initial exposure to some experimental conditions. Otherwise, the results from Exp. I are accurately described by the matching function.

DISCUSSION

In Exp. I, the relative frequency of responding on one of two keys approximately equalled the relative reciprocal of the length of the interresponse time reinforced on that key, when the relative frequency and relative magnitude of reinforcement both equalled 0.50. This matching function is approximately the same function as that obtained previously when two interresponse times were reinforced on a single key (Shimp, 1969). That is, the relative length of an interresponse time controlled the relative frequency of that interresponse time in the present two-key experiment in the same way as it did in Shimp's one-key experiment.

EXPERIMENT II

In this experiment, both the relative frequency and relative magnitude of reinforcement were varied for each of two groups of pigeons. As explained above, the two reinforced interresponse times for a group in the present two-key experiment were those used previously with corresponding one-key concurrent schedules of reinforcement for two interresponse times (Shimp, 1968; Staddon, 1968). The two reinforced interresponse times

for Group A were those used by Staddon (2 to 3 sec and 10 to 11 sec). The two reinforced interresponse times for Group B were those used by Shimp (1.5 to 2.5 sec and 3.5 to 4.5 sec).

METHOD

Subjects

Six male White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. There were three pigeons in each of the two groups. Birds 16 and 17 of Group A were experimentally naive; the other four birds had been used previously in schedules that differentially reinforced behavior other than pecking, *i.e.*, DRO schedules.

Procedure

The only procedural differences between Groups A and B were the lengths of the reinforced interresponse times. The reinforced interresponse times for Group A were 2 to 3 sec and 10 to 11 sec for the first two conditions of the experiment. However, the relatively narrow width of the longer interresponse time, together with the present method of scheduling reinforcements, reduced the total reinforcement density to very low values. Other data suggest that low reinforcement densities change functions similar to those under examination in the present experiment (Shimp, 1970). Therefore, in the third condition, and all subsequent conditions, the band width of the longer interresponse time was increased from 1 sec to 3 sec, thereby extending the upper bound of the longer interresponse time from 11 to 13 sec. For Group A, the relative reciprocal for the shorter interresponse time was 0.83. The reinforced interresponse times for Group B were 1.5 to 2.5 sec and 3.5 to 4.5 sec. The relative reciprocal for the shorter interresponse time was 0.70.

Table 3 describes the experimental conditions for Group A and Group B. Note that the probability of reinforcement and the relative magnitude of reinforcement never were varied simultaneously. That is, either the probability of reinforcement or the relative magnitude of reinforcement equalled 0.50 in any one condition. Each session lasted 45 min.

RESULTS

Tables 4 and 5 show the number of responses and reinforcements on the left and

Table 3
Experimental Conditions for Exp. II

Condition Number	No. of Sessions						Probability of Reinforce- ment on the Left Key (π)	Relative Magnitude of Reinforce- ment on the Left Key (F)	Feeder Times for the Left and Right Keys (sec)
	(Group A)			(Group B)					
	Bird 16	Bird 17	Bird 13	Bird 11	Bird 7	Bird 3			
1	11	11	11	20	22	22	0.50	0.50	3.0, 3.0
2	12	12	12	19	15	15	0.25	0.50	3.0, 3.0
3	30	30	25	21	26	11	0.10	0.50	3.0, 3.0
4	11	9	11	12	20	13	0.75	0.50	3.0, 3.0
5	9	11	8	8	17	9	0.50	0.50	3.0, 3.0
6	14	18	17	12	20	26	0.50	0.25	1.5, 4.5
7	13	8	14	18	11	20	0.50	0.75	4.5, 1.5
8	5	4	5	7	5	7	1.00	0.50	3.0, 3.0
9	20	20	20	10	12	12	0.0	0.50	3.0, 3.0
10	10	10	15	15			0.10	0.50	3.0, 3.0
11	12	12	12	8			0.05	0.50	3.0, 3.0
							0.75*	0.50	3.0, 3.0
12	14	13	16				0.50	0.25	1.5, 4.5

*For Bird 11

right keys for each of the three birds in Groups A and B, respectively. As in Table 2 for Exp. I, the data in Tables 4 and 5 are from the last three sessions of each experimental condition.

The panels in Fig. 2 show the functions obtained for each of the birds in Group A and Group B. The relative frequency of responding on the left key is plotted against either the obtained relative frequency of reinforcement or the relative feeder duration. The curvilinear functions in Fig. 2 are negatively accelerated, monotonically increasing functions of the reinforcement parameters. The filled circles in Fig. 2 represent the relative frequency of responding as a function of relative frequency of reinforcement; the triangles represent the relative frequency of responding as a function of relative feeder duration. The relative frequency of responding on the left key when π equalled 0.25 was about equal to the relative frequency of responding on the key when F equalled 0.25. This near equality in relative frequency of responding was also obtained when both π and F equalled 0.75.

DISCUSSION

For both Group A and Group B of Exp. II, the relative frequency of responding on one of two keys was a negatively accelerated, monotonically increasing function of the relative frequency of reinforcement for the interresponse time reinforced on that key. Figure 3

compares the curvilinear functions obtained here with those obtained previously when the relative frequency of reinforcement was varied for the same two interresponse times reinforced on a single key (Shimp, 1968; Staddon, 1968). In the left panel of Fig. 3, the function obtained for Group A is compared with the function obtained in Staddon's experiment. Thus, in the left panel, the lower bounds of the two reinforced interresponse times in each experiment were 2 sec and 10 sec. In the right panel, the function obtained for Group B is compared with the function obtained in Shimp's experiment. Thus, in the right panel, the lower bounds of the two reinforced interresponse times in each experiment were 1.5 sec and 3.5 sec. In the left panel, there is a striking correspondence between the results for the one-key and two-key experiments. In the right panel, there is greater variability in both experiments than in the left panel, but the results for these one-key and two-key experiments also are indistinguishable from one another.

Figure 4 compares the functions obtained when the relative magnitude of reinforcement was varied in corresponding one-key and two-key experiments. The functions for the one-key and two-key experiments are similar except that when the relative magnitude of reinforcement was 0.25, two birds in Group B had a noticeably lower relative frequency of responding than the other four birds.

Table 4
Experiment II: Number of Responses and Reinforcements on Left and Right Keys for Group A

Condition Number	Number of Responses on Left Key			Number of Responses on Right Key			Number of Reinforcements on Left Key			Number of Reinforcements on Right Key		
	Bird 16	Bird 17	Bird 13	Bird 16	Bird 17	Bird 13	Bird 16	Bird 17	Bird 13	Bird 16	Bird 17	Bird 13
1	486	840	526	85	105	164	13	6	8	5	6	8
	375	759	612	67	113	155	7	6	13	3	3	7
	400	759	709	91	102	163	12	9	8	6	5	8
2	383	325	442	217	222	243	2	2	0	5	20	2
	329	338	492	198	211	208	3	3	2	13	8	9
	322	356	424	261	207	196	2	3	2	6	13	15
3	137	506	227	159	153	228	4	1	2	45	20	29
	317	565	390	150	169	203	5	6	6	26	18	17
	166	539	577	184	150	225	3	2	0	41	18	10
4	873	1053	1091	61	61	82	22	20	31	9	3	6
	788	904	1103	97	89	135	18	6	26	9	5	9
	748	1104	1304	79	57	92	27	28	25	5	6	8
5	441	735	663	171	86	189	11	10	9	14	11	15
	635	744	667	127	97	172	12	10	10	12	11	19
	600	772	819	96	91	155	15	9	17	17	14	10
6	518	670	284	92	144	205	12	26	5	10	14	7
	407	534	703	104	161	127	5	20	18	7	22	8
	404	491	824	112	223	138	18	28	14	10	10	10
7	799	991	855	89	90	93	12	7	12	8	9	13
	763	1073	1036	103	57	86	16	17	13	11	13	10
	751	1096	1022	106	62	80	11	16	11	11	16	11
8	1139	1564	1591	0	0	2	76	79	79	0	0	0
	1160	1422	1471	0	0	0	77	79	84	0	0	0
	1012	1379	1433	0	0	0	75	79	79	0	0	0
9	26	19	48	190	225	297	0	0	0	45	14	46
	26	26	14	219	198	300	0	0	0	44	47	52
	34	17	34	209	189	285	0	0	0	37	46	48
10	229	383	213	158	162	188	4	2	2	20	59	30
	213	405	162	153	141	206	4	4	3	23	22	29
	213	281	245	155	183	204	3	4	5	30	32	27
11	101	187	107	183	152	264	0	2	1	25	30	31
	63	157	113	184	168	253	2	2	1	30	32	32
	83	164	78	127	162	266	2	1	2	33	29	24
12	378	432	289	115	136	187	10	14	19	12	13	19
	365	359	240	118	135	187	10	9	18	12	12	20
	372	343	259	144	119	206	14	15	18	10	8	15

When one-key and two-key interresponse-time data are compared, as in Fig. 3 and 4, there is a potential complication because different ways to count the number of interresponse times in an interresponse-time frequency distribution have been used in different experiments. In the present paper, the interresponse-time distribution on a key is described by the total number of responses on that key. This number includes, of course, not only the responses terminating interresponse times within the reinforced interval, but all other responses as well, including switching

responses, which do not terminate any interresponse time at all. There are two related ways to justify, in the present case, the use of the total number of responses on a key to summarize the interresponse-time distribution on that key. First, two other ways of counting the number of interresponse times in a distribution were used, and each gave the same picture of the data as did the method used here. These other two ways were: (a) all responses except those terminating very short interresponse times and switching responses were counted, and; (b) only responses termi-

Table 5
Experiment II: Number of Responses and Reinforcements on Left and Right Keys for Group B

Condition Number	Number of Responses on Left Key			Number of Responses on Right Key			Number of Reinforcements on Left Key			Number of Reinforcements on Right Key		
	Bird 11	Bird 7	Bird 3	Bird 11	Bird 7	Bird 3	Bird 11	Bird 7	Bird 3	Bird 11	Bird 7	Bird 3
1	908	680	701	312	279	206	8	15	23	10	26	16
	1184	791	722	310	240	240	19	22	16	8	8	23
	1130	785	608	270	222	297	4	12	15	13	13	15
2	785	360	343	504	462	423	9	7	5	45	26	23
	774	425	359	534	506	498	9	6	7	37	31	29
	772	363	384	525	495	484	7	8	11	33	28	39
3	527	144	137	467	573	571	6	8	4	50	54	44
	624	77	149	455	632	553	5	4	5	44	55	47
	418	136	163	463	622	546	10	10	2	49	41	52
4	1204	844	1257	407	170	142	47	46	52	8	11	9
	1246	823	1137	397	162	233	51	46	42	10	9	15
	1148	1050	1182	534	164	150	38	45	38	15	10	14
5	1091	655	716	376	230	308	22	23	19	29	21	22
	994	683	891	313	222	268	29	27	29	26	24	19
	1047	691	871	359	236	298	26	34	26	12	21	23
6	705	411	277	399	447	466	31	18	26	25	21	19
	588	319	320	412	473	507	32	23	27	25	20	29
	604	242	326	385	541	520	36	20	29	25	21	17
7	925	984	1145	239	211	239	25	27	26	21	22	25
	996	868	1068	230	202	222	22	28	31	23	21	21
	1009	831	1026	236	183	196	24	30	22	24	23	19
8	1613	1696	1610	30	4	1	73	75	78	0	0	0
	1767	1662	1489	10	7	2	74	74	78	0	0	0
	1701	1677	1506	14	3	7	75	75	80	0	0	0
9	20	42	86	765	595	598	0	0	0	68	78	63
	7	7	33	753	600	652	0	0	0	36	70	66
	6	0	52	747	630	548	0	0	0	65	71	68
10	331			551			11			47		
	327			511			5			57		
	333			613			5			50		
11	1133			164			50			15		
	1334			126			47			9		
	1272			116			44			12		

nating interresponse times in the reinforced intervals were counted. Second, the various ways of counting responses in interresponse-time distributions have not seemed to reduce interexperiment comparability across previous experiments. For example, the matching-to-relative reciprocal phenomenon emerges from numerous different ways of summarizing an interresponse-time distribution (see Shimp, 1970, page 8.). Presumably, these different ways of counting the responses in an interresponse-time distribution all give the same outcome because all of them include most of the responses in the distribution. That is, the different counts

are highly correlated because they are based on approximately the same responses. The responses in the reinforced interval, plus responses terminating interresponse times just below the lower bound of the reinforced interval, generally include most of the responses. For example, the reinforced interresponse times on the left key for Group A in Exp. II fell between 2 and 3 sec and the percentage of the responses on the left key that terminated interresponse times between 1 and 3 sec was 0.821, 0.871, and 0.905, for Birds 13, 16, and 17, respectively. (These and the following percentages are averages over the days for which data are presented in Tables 4 and 5.)

Fig. 2. The relative frequency of responding on the left key as a function of the obtained relative frequency of reinforcement on that key (filled circles); and the relative frequency of responding on the left key as a function of the relative magnitude of reinforcement on that key (triangles). The upper three panels show the individual data for the pigeons in Group A. The lower three panels show the individual data for the pigeons in group B.

The reinforced interresponse times on the right key for Group A fell between 10 and 13 sec and the percentage of responses on the right key that terminated interresponse times between 6 and 13 sec was 0.885, 0.829, and 0.808, for Birds 13, 16, and 17, respectively. The same intervals of 1 to 3 and 6 to 13 sec include most of the responses in the two interresponse-time distributions in the previous one-key experiment analogous to Group A of Exp. II (Staddon, 1968). Similarly, the reinforced interresponse times on the left key for Group B fell between 1.5 and 2.5 sec and the percentage of the responses on the left key that terminated interresponse times between 0.75 and 2.5 sec were 0.824, 0.937, and 0.962, for Birds 3, 7, and 11, respectively. The rein-

forced interresponse times on the right key for Group B fell between 3.5 and 4.5 sec and the percentage of responses on the right key that terminated interresponse times between 2.5 and 4.5 sec was 0.703, 0.845, and 0.775, for Birds 3, 7, and 11, respectively. The same intervals of 0.75 to 2.5 sec and 2.5 to 4.5 sec include most of the responses in the two interresponse-time distributions in the previous one-key experiment analogous to Group B of Exp. II (Shimp, 1968). Equipment limitations imposed severe restraints on the recording of interresponse times in both Exp. I and II, but the restraints in Exp. I, in which the reinforced interresponse times changed over conditions, was especially severe and precluded a uniform basis for computing per-

Fig. 3. A comparison of the functions for one-key and two-key experiments when the relative frequency of reinforcement is varied across two interresponse times. The left panel compares Staddon's (1968) data with the data for Group A of Exp. II. The right panel compares Shimp's (1968) data with the data for Group B of Exp. II. The filled circles represent the relative frequency of shorter interresponse times in Staddon's experiment and the relative frequency of shorter interresponse times in Shimp's experiment. The triangles represent the relative frequency of responding on the left key for Groups A and B.

Fig. 4. A comparison of the functions for one key and two-key experiments when the relative magnitude of reinforcement is varied across two interresponse times. The filled circles represent the relative frequency of shorter interresponse times in Shimp's (1968) experiment. The triangles represent the relative frequency of responding on the left key for Group B of Exp. II.

centages such as was used above for Exp. II. However, computations for Exp. I of percentages based on interresponse-time intervals that shifted as the reinforced interresponse-time intervals shifted suggested the same principle as the above percentages for Exp. II: responses in, and just before, the reinforced interval include a high percentage of all the responses in the distribution.

An additional point of interest in this experiment is illustrated in Fig. 2. For values of 0.25 and 0.75 on the X coordinate, the relative frequency of responding as a function of the relative frequency of reinforcement was approximately equal to the relative frequency of responding as a function of the relative magnitude of reinforcement. The same approximate equality between the effect of relative frequency and relative magnitude of reinforcement was demonstrated in Shimp's (1968) experiment, although for different values on the X coordinate. This equality suggests a functional equivalence between the effects of relative frequency and relative magnitude of reinforcement, at least for not-too-extreme values of π and F .

GENERAL DISCUSSION

The functions obtained in Exp. I and II with the present two-key concurrent paced VI paced VI schedule are approximately the same as the functions obtained previously with one-key concurrent schedules of reinforcement for two interresponse times (Shimp, 1968, 1969; Staddon, 1968).

In Exp. I, the relative reciprocal of the length of one of two interresponse times was varied in a two-key procedure. Figure 1 showed that the relative frequency of responding on a key approximately matched the relative reciprocal of the length of the interresponse time reinforced on that key. This same matching function was obtained previously when the relative reciprocal of the length of an interresponse time was varied for one of two interresponse times reinforced on a single key (Shimp, 1969).

In Exp. II, either the relative frequency or relative magnitude of reinforcement was varied for interresponse times reinforced on two keys. Figure 3 suggested that the interresponse times reinforced on one key in Staddon's (1968) experiment, and the interresponse times reinforced on one key in Shimp's (1968) experiment, depended on the relative frequency of reinforcement in the same way as did the same interresponse times reinforced on two keys for Group A and Group B, respectively. Figure 4 suggested that the two interresponse times reinforced on one key in Shimp's (1968) experiment depended on the relative magnitude of reinforcement in much the same way as did the same interresponse times when reinforced on two keys for Group B.

In Shimp's (1968, 1969) one-key experiments, the reinforced interresponse times were associated with discriminative stimuli. However, neither Staddon's (1968) experiment nor the present two-key experiments used discriminative stimuli. Whether or not discriminative stimuli are used apparently does not much matter, since the one-key and two-key functions compared here are approximately the same.

In the present experiment, there was a one-to-one correspondence between keys and classes of reinforced interresponse times. That is, when a bird chose one of two keys, it in effect also chose one of two classes of reinforced interresponse times. The way choices were distributed across keys in the present experiment was the same as the way in which interresponse times were distributed in previous, corresponding single-key experiments. Hopefully, this discovery will contribute to the theoretical unification of interresponse times and choice behavior.

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