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PREFERENCE FOR MIXED VERSUS CONSTANT DELAY OF REINFORCEMENT[1]

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Preference for constant and mixed delay of reinforcement was studied using concurrent equal variable-interval schedules. For four pigeons, pecking one key was reinforced following constant delays of 8 sec and mixed delays of 6 or 10 and 2 or 14 sec. Pecking a second key was reinforced following constant delays of 0, 8, 16, and 32 sec. For two additional pigeons, pecking one key was reinforced following delays of 30, 15 or 45, 5 or 55, and 0 or 60 sec. Reinforcements on the other key were delayed 30 sec. It was found that (a) pigeons preferred mixed relative to constant delay of reinforcement, and (b) preference for mixed delay of reinforcement increased as the range of delay interval variability increased.

Key words: choice behavior, concurrent schedules, delay of reinforcement, key peck, pigeon

In Shimp's (1969) extension of Expected Utility theory to various free-operant behavior paradigms, including concurrent variable-interval schedules of positive reinforcement modified by delay of reinforcement, there is no distinction between delay intervals of constant duration and delay intervals of varying duration (see Shimp, 1969, p. 103, Equation 4). The absence of a distinction implies that these two types of delayed reinforcement do not differentially influence choice behavior. However, there is evidence both that aperiodic reinforcement schedules are preferred to periodic schedules (*e.g.*, Fantino, 1967; Herrnstein, 1964; Killeen, 1968, Experiment 1; Sherman and Thomas, 1968) and that delay intervals of varying duration are preferred to delay intervals of constant duration (Logan, 1965, Experiment 1; Pubols, 1962). Although the latter two investigators reported results that contradict Shimp's implication that choice behavior is not differentially influenced by delay intervals of constant and varying duration, both Logan and Pubols used a discrete-trial procedure and, therefore, their results may not be appropriate for an evaluation of Shimp's Equation 4.

The present study employed a free-operant procedure in which delay intervals of mixed length were superimposed on the reinforcers scheduled on one response key while delay intervals of constant length were superimposed on the reinforcers assigned to another, concurrently available, response key. If Shimp's Equation 4 is correct, systematic preferences would not develop for either response key.

METHOD

Subjects

Six White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. Four pigeons were experimentally naive (Pigeons 6, 7, 9, 11); two (Pigeons 8 and 10) had been used in previous research on concurrent reinforcement schedules.

Apparatus

An operant chamber for pigeons was equipped with two response keys (2 cm diameter) with centers 6 cm apart. The keys were mounted 21.5 cm above the grid floor. A minimum force of approximately 0.15N operated the keys and a relay that provided auditory feedback. Except during delay intervals and feeder operations, the left (right) key was transilluminated by a red (green) light. Reinforcement consisted of 3- to 5-sec access to mixed grain. A houselight (24-W white bulb) was located above each response key. A white

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masking noise was always present during each experimental session. The standard programming equipment, including two cumulative recorders, timers, counters, and relays was located in a room adjacent to the room containing the experimental chamber.

Pretraining Procedure

After magazine and key-peck training, each bird received one session in which the response keys were transilluminated according to the alternating pattern red, green, red, *etc.* Each peck on a key turned off the keylight and was immediately reinforced. During both pretraining and delay training, experimental sessions ended when 60 reinforcements had been delivered.

Delay Training Procedure

To establish a stable baseline of performance, two variable-interval reinforcement schedules independently arranged reinforcements on the concurrently available response keys. Both schedules had an average interreinforcement interval of 60 sec. Each schedule was constructed using the sequence of intervals: 75, 9, 60, 97, 15, 38, 45, 113, 83, 52, 105, 67, 22, 90, 120, 9, and 22 sec. There was no changeover delay; *i.e.,* reinforcements assigned to either key during responding on the alternate key could be obtained (after an appropriate delay interval) by the initial response following a changeover.

Constant delays of 8 sec or mixed delays of either 6 and 10 sec or 2 and 14 sec were correlated with the reinforcements arranged by the right key (Mixed Delay Key) for Pigeons 6, 7, 9, and 11. Constant delays of 0, 8, 16, and 32 sec were imposed on the reinforcements arranged by the left key (Constant Delay Key). The sequence of delay conditions was determined arbitrarily for each key and the same sequence was used for each subject. For Pigeons 8 and 10, constant delays of 30 sec were superimposed on the reinforcements arranged on the left key (Constant Delay Key). Delays of 15 and 45, 0 and 60, 30, and 5 and 55 sec were superimposed on the reinforcements arranged on the right key (Mixed Delay Key). Mixed delays of 15 and 45 sec were studied a second time with Pigeon 10. For all birds, the members of each pair of mixed delay intervals were arranged in a random sequence, with the limitation that each member occurred equally often each day. This sequence was changed at irregular intervals during the experiment. A given pair of delay conditions was maintained on the two keys until relative response rate for each bird was within $\pm 5\%$ of its mean rate for a sliding block of five sessions.

During delay intervals and feeder operations, the keylights were turned off, responding no longer produced auditory feedback, time was not recorded, and both reinforcement programmers stopped. Pigeons 6, 7, 9, and 11, unlike Pigeons 8 and 10, did not develop stable preferences with the use of an unsignalled delay procedure. Consequently, for those four subjects, the left houselight was continuously illuminated during the delay intervals entered as a consequence of responding on the left key. During delay intervals entered as a consequence of responding on the right key, the right houselight flickered at the rate of four times per second. Responding during the delay intervals had no scheduled consequence.

RESULTS

The number of experimental sessions, mean response rate, standard deviations of response rate for the terminal five sessions, time, number of changeovers, and number of reinforcements for Pigeons 6, 7, 9, and 11 are reported in Tables 1, 2, and 3. Corresponding data for Pigeons 8 and 10 are reported in Table 4.

Relative rate of responding was computed with respect to the Mixed Delay Key (responses on Mixed Delay Key divided by the total responses on the Mixed and Constant Delay Keys). Mean relative rate of responding for the terminal five days of each experimental condition is reported in Table 5. (Tables 4 and 5 present both the initial and redetermined data of Pigeon 10; the redetermined values are enclosed in parentheses.)

The key associated with the shorter average delay of reinforcement was consistently preferred by all subjects. These results agree with those of Anderson (1932), Chung (1965), Chung and Herrnstein (1967), Clements (1928), and Sams and Tolman (1925).

For each delay value on the Constant Delay Key, Pigeons 6, 9, and 11 emitted a greater proportion of their pecks on the Mixed Delay Key when mixed delays of 6 and 10 sec or 2 and 14 sec were scheduled on the latter key

Table 1

Number of sessions (Sess), mean response rate, standard deviation of response rate (SD), time (in min), changeovers (COs), and reinforcements (Rfts) on each key during the terminal five sessions of each condition when delays of 8 sec were scheduled on the mixed delay key.

Constant Key Delay	*Sess*	*Key*	*Mean Resp Rate*	*SD*	*Time*	*COs*	*Rfts*
SUBJECT 6							
0 sec	33	M	64.5	8.8	29.7	1675	145
		C	77.9	9.5	120.9	1676	155
8 sec	35	M	98.5	5.8	53.4	4203	142
		C	87.9	6.1	94.4	4204	158
16 sec	34	M	84.5	3.8	78.4	3300	145
		C	88.9	6.8	67.4	3299	155
32 sec	18	M	65.9	5.5	137.6	1239	164
		C	96.9	14.0	22.5	1240	136
SUBJECT 7							
0 sec	33	M	44.8	2.9	57.5	2001	149
		C	50.7	4.7	91.4	2000	151
8 sec	33	M	49.1	5.7	90.3	1942	151
		C	45.6	11.3	63.2	1941	149
16 sec	35	M	60.8	3.5	140.4	921	160
		C	60.1	3.8	19.2	921	140
32 sec	19	M	48.5	2.7	208.7	195	211
		C	51.5	6.1	4.7	195	89
SUBJECT 9							
0 sec	32	M	41.9	4.6	25.3	732	137
		C	45.0	2.4	139.0	731	163
8 sec	35	M	42.2	3.3	77.5	1557	149
		C	57.3	6.8	73.6	1559	151
16 sec	35	M	40.9	3.5	131.8	654	161
		C	39.6	5.2	30.6	656	139
32 sec	19	M	37.8	3.9	178.1	238	194
		C	23.9	4.3	16.2	238	106
SUBJECT 11							
0 sec	31	M	106.7	8.9	19.7	1968	147
		C	77.9	9.2	129.0	1967	153
8 sec	35	M	87.0	4.9	73.9	4085	150
		C	80.0	1.4	76.8	4083	150
16 sec	35	M	85.5	3.1	98.5	2298	150
		C	62.1	3.8	54.0	2296	150
32 sec	19	M	75.6	5.1	166.3	459	179
		C	43.2	4.3	10.9	460	121

Table 2

Number of sessions (Sess), mean response rate, standard deviation of response rate (SD), time (in min), changeovers (COs), and reinforcements (Rfts) on each key during the terminal five sessions of each condition when mixed delays of 6 and 10 sec were scheduled on the mixed delay key.

Constant Key Delay	*Sess*	*Key*	*Mean Resp Rate*	*SD*	*Time*	*COs*	*Rfts*
SUBJECT 6							
0 sec	42	M	72.2	5.9	39.7	2561	148
		C	75.2	5.7	108.0	2560	152
8 sec	34	M	77.1	8.8	62.4	3092	151
		C	60.0	7.4	84.8	3092	149
16 sec	40	M	63.7	2.4	122.8	2001	152
		C	106.8	8.6	29.0	2000	148
32 sec	14	M	62.4	5.0	202.4	257	211
		C	39.6	8.9	8.3	258	89
SUBJECT 7							
0 sec	42	M	58.6	3.6	53.9	2137	145
		C	60.9	4.7	98.0	2136	155
8 sec	35	M	50.3	4.4	97.3	1938	154
		C	42.9	4.4	56.3	1938	146
16 sec	41	M	45.0	3.8	153.1	731	164
		C	75.4	10.5	11.0	732	136
32 sec	14	M	60.0	3.0	179.6	395	188
		C	58.8	4.0	8.2	392	112
SUBJECT 9							
0 sec	42	M	43.7	2.1	50.4	1145	148
		C	49.9	4.4	103.0	1147	152
8 sec	35	M	49.2	4.5	63.4	1440	144
		C	40.3	1.6	92.4	1440	156
16 sec	41	M	42.5	1.1	131.8	875	158
		C	54.7	6.8	27.2	874	142
32 sec	14	M	36.4	1.8	186.3	195	189
		C	48.0	6.7	5.3	196	111
SUBJECT 11							
0 sec	42	M	71.0	5.3	20.6	1180	143
		C	80.7	6.5	135.3	1180	157
8 sec	35	M	92.2	5.5	57.3	3655	149
		C	71.3	4.1	88.2	3656	151
16 sec	42	M	54.4	2.7	117.1	1481	155
		C	45.9	4.4	37.8	1483	145
32 sec	14	M	60.3	7.2	185.0	250	197
		C	34.9	4.4	7.8	252	103

than when constant delays of 8 sec were scheduled on the Mixed Delay Key. In addition, these subjects responded more on the Mixed Delay Key when mixed delays of 2 and 14 sec were scheduled on that key than when mixed delays of 6 and 10 sec were scheduled on the Mixed Delay Key.

Mean relative rate of responding increased on the Mixed Delay Key for Pigeons 8 and 10 as the degree of delay interval variability increased on that key. These results were supported by data from Pigeons 6, 7, 9, and 11 when delays of 8 sec were scheduled on the Constant Delay Key and mixed delays of 2 and 14 sec were scheduled on the Mixed Delay Key. In that experimental condition, each subject preferred the Mixed Delay Key.

Table 3

Number of sessions (Sess), mean response rate, standard deviation of response rate (SD), time (in min), changeovers (COs), and reinforcements (Rfts) on each key during the terminal five sessions of each condition when mixed delays of 2 and 14 sec were scheduled on the mixed delay key.

Constant Key Delay	*Sess*	*Key*	*Mean Resp Rate*	*SD*	*Time*	*COs*	*Rfts*
Subject 6							
0 sec	24	M	74.5	3.5	59.0	3193	146
		C	71.9	4.0	88.9	3189	154
8 sec	27	M	79.5	4.0	97.8	3170	153
		C	108.5	5.1	47.9	3171	147
16 sec	43	M	78.6	1.1	130.2	1844	156
		C	119.1	4.7	27.6	1844	144
32 sec	10	M	82.9	2.6	139.2	1209	162
		C	103.1	4.6	20.9	1211	138
Subject 7							
0 sec	23	M	53.5	4.6	48.0	1919	153
		C	55.1	3.2	101.1	1920	147
8 sec	27	M	40.2	1.7	109.0	1653	157
		C	48.5	5.9	48.5	1656	143
16 sec	43	M	48.3	2.3	130.8	1235	157
		C	59.2	5.6	24.1	1235	143
32 sec	10	M	57.8	3.2	166.9	468	179
		C	56.0	3.6	8.9	471	121
Subject 9							
0 sec	23	M	44.9	2.7	54.1	1318	147
		C	55.5	4.5	102.4	1315	153
8 sec	27	M	44.3	1.9	110.3	1927	152
		C	99.4	7.7	42.4	1928	148
16 sec	43	M	48.4	2.3	137.0	823	158
		C	75.8	3.1	19.4	825	142
32 sec	10	M	55.2	1.2	170.5	325	178
		C	73.1	9.2	6.8	325	122
Subject 11							
0 sec	24	M	101.1	6.0	31.2	2940	147
		C	78.3	6.1	120.3	2939	153
8 sec	27	M	93.0	4.5	102.3	3667	151
		C	91.2	3.8	47.3	3667	149
16 sec	43	M	76.9	3.6	149.6	816	169
		C	49.0	5.5	19.1	813	131
32 sec	10	M	60.2	1.0	194.7	238	204
		C	32.7	4.0	7.5	240	96

Table 4

Number of sessions (Sess), mean response rate, standard deviation of response rate (SD), time (in min), changeovers (COs), and reinforcements (Rfts) on each key during the terminal five sessions.

Mixed Delay	*Sess*	*Key*	*Mean Resp Rate*	*SD*	*Time*	*COs*	*Rfts*
Subject 8							
30	39	M	37.5	3.2	86.8	1136	154
		C	38.8	2.2	70.4	1137	146
15 & 45	35	M	42.3	2.9	94.2	1662	150
		C	60.2	5.3	59.9	1661	150
5 & 55	28	M	65.2	3.8	100.0	1478	153
		C	54.0	3.4	54.8	1478	147
0 & 60	17	M	62.2	5.0	191.6	248	199
		C	44.2	16.0	6.8	250	101
Subject 11							
30	39	M	13.9	2.4	105.4	529	154
		C	12.5	2.1	67.4	529	146
15 & 45	35	M	18.7	1.3	62.3	659	146
	(21)		(27.4)	(3.2)	(141.8)	(891)	(174)
		C	17.6	2.2	105.4	661	154
			(33.8)	(5.0)	(39.9)	(891)	(126)
5 & 55	28	M	26.7	4.2	178.7	280	192
		C	19.4	3.6	16.5	279	108
0 & 60	17	M	48.3	4.1	246.5	83	251
		C	16.8	6.5	4.8	84	49

DISCUSSION

The present results indicate that pigeons prefer mixed relative to constant delay of reinforcement and that this preference increases as the range of the mixed delay interval lengths increases. These data are in accord with the findings of previous investigators, using free-operant methodology, that organisms prefer aperiodic over periodic schedules of reinforcement (Fantino, 1967; Herrnstein, 1964; Killeen, 1968, Experiment 1; Sherman and Thomas, 1968). In addition, the present data replicate the reports of Logan (1965, Experiment 1) and Pubols (1962), both of whom used a discrete-trial procedure, that rats prefer variable relative to constant delay of reinforcement.

In combination with these previous results, the present results recommend a reconsideration of Shimp's assumption that choice behavior is not differentially influenced by reinforcement delays of constant and varying duration. Although the necessity of a reformulation of Shimp's extension of Expected Utility Theory to concurrent schedules of delayed positive reinforcement is suggested, construction of a specific alternative is not warranted on the basis of the present preliminary data. Further research is necessary to determine the most appropriate mathematical representation of varying delay length. Among the indices to be considered for this purpose are the various averages, variability measures, and mathematical transformations of these. In addition, any comprehensive reformulation probably should

Table 5

Mean relative rate of responding on the mixed delay key for the terminal five sessions of each experimental condition.

Constant Key Delay (sec)	Mixed Key Delay (sec) 8	6 & 10	2 & 14
SUBJECT 6			
0	0.17	0.26	0.41
8	0.39	0.49	0.60
16	0.52	0.72	0.76
32	0.81	0.97	0.84
SUBJECT 7			
0	0.36	0.35	0.32
8	0.61	0.67	0.65
16	0.88	0.90	0.82
32	0.98	0.96	0.95
SUBJECT 9			
0	0.18	0.30	0.30
8	0.44	0.46	0.54
16	0.82	0.79	0.82
32	0.95	0.96	0.95
SUBJECT 11			
0	0.18	0.12	0.25
8	0.51	0.45	0.69
16	0.72	0.79	0.93
32	0.96	0.98	0.98

	Mixed Key Delay (sec) 30	15 & 45	5 & 55	0 & 60
SUBJECT 8				
30	0.54	0.53	0.69	0.97
SUBJECT 10				
30	0.63	0.39 (0.74)	0.93	0.99

represent the just-noticeable difference for temporal variability; *i.e.*, the minimum degree of variability of the aperiodic delay intervals that can be discriminated from delay intervals of constant length. Finally, note that the present investigation employed only two values to represent a given condition of varying delay of reinforcement. Any reformulation of Shimp's Equation 4 should be based on research that incorporates a greater number of delay values for each condition of varying delay of reinforcement.

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