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Order of Experimental Conditions and Empirical Parameters of the Generalized Matching Law

El Orden de las Condiciones Experimentales y de Parámetros Empíricos de la Ley Generalizada de Igualación.

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ABSTRACT

Three experimentally naive pigeons were submitted to concurrent variable-interval variable-interval schedules in a three-key procedure. A variable-interval 60 s schedule was always associated with the right/blue key. In different experimental conditions, the variable interval schedule associated with the left/red key was varied in the following order: 240, 180, 300, 360, 90, 60, and 15 s. In spite of the non-recommended order of experimental conditions, exponents of the generalized matching equation show matching of response ratios to reinforcement ratios.

DESCRIPTORS: Bias, Matching, Concurrent schedules, Conditions order, Keypecking, Pigeons.

RESUMEN

Tres palomas experimentalmente ingenuas fueron expuestas a programas concurrentes intervalo-variable intervalo-variable en un procedimiento de tres teclas. Un programa intervalo variable 60 seg. estuvo asociado siempre con la tecla derecha/azul. El programa de intervalos variables asociado con la tecla izquierda/roja fue variado en diferentes condiciones siguiendo el orden: 240, 180, 300, 360, 90, y 15 seg. A pesar del poco recomendarle orden de las condiciones experimentales, los exponentes de la ecuación de

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igualación mostraron igualación de las razones de respuesta a las razones de reforzamiento.
DESCRIPTORES: Igualación, programas concurrentes, Orden de condiciones, picotear, palomas.

Herrnstein's (1961; 1970) efforts toward the quantification of the law of effect have been responsible for a considerable part of the work on the experimental analysis of behavior over the last 20 years (*e.g.*, de Villiers, 1977). As formulated by Herrnstein (1970), the so called matching law states that the distribution of responses or time between alternatives matches the distribution of reinforcement between those alternatives:

$$(R_1/R_2) = (r_1/r_2) \tag{1}$$

and

$$(T_1/T_2) = (r_1/r_2) \tag{2}$$

where *R, T,* and *r* refer to responses, time, and reinforcements, and subscripts denote schedules of the concurrent pair.

Published data refuting Herrnstein's equation were analyzed by Baum (1974), who suggested a power function:

$$(R_1/R_2) = k\,(r_1/r_2)^a \tag{3}$$

and

$$(T_1/T_2) = k\,(r_1/r_2)^a \tag{4}$$

where *k* and *a* are empirical parameters; *k* is a measure of bias, *a* is a measure of the sensitivity of behavior ratios to reinforcement ratios (Baum, 1974; 1979). When $a = k = 1.0$, Equations 3 and 4 are equivalent to Equations 1 and 2. If only *k* is different from 1.0, Equations 3 and 4 account for matching of behavior ratios to reinforcement ratios under experimental conditions producing bias (*e.g.*, LaBounty & Reynolds, 1973; Trevett, Davison & Williams, 1972; Bacotti, 1977). When *k* has different values in Equations 3 and 4 (Davison, 1982) those equations also account for matching of behavior ratios to reinforcement ratios under conditions of unequal local response rates ($R_1/T_1 \neq R_2/T_2$): when response bias (k_R) is different from time bias (k_T), the following equality holds for local response rates:

$$k_T\,(R_1/T_1) = k_R\,(R_2/T_2) \tag{5}$$

Exponent values in Equations 3 and 4, however, have been responsible for much of the controversy around the generalized matching law (Baum, 1974). Data from experiments with concurrent schedules have originated values of *a* equal to (matching), greater (overmatching) and lower (undermatching) than 1.0 (*cf.*, Baum, 1979; Wearden & Burgess, 1982; Todorov, Oliveira-Castro, Hanna, Bittencourt de Sá, & Barreto, 1983), with undermatching as the most frequent occurrence. Previous experience with concurrent schedules (Todorov *et al.*, 1983), number of sessions per condition (McSweeney, Melville, Buck, & Whipple, 1983; Todorov *et al.*, 1983), and differential sensitivity to arithmetic and exponential variable-interval tapes (Taylor & Davison, 1983) have been suggested as sources of undermatching. Baum (1979) pointed out that the lack of discriminability of the schedule might result in undermatching (by definition, absence of discriminability means indifference of responding to changes in reinforcement ratios); de Villiers (1977) prescribed the balancing out of experimental conditions in order to obtain matching –that is, if in Condition 1 the schedule on the left in associated with higher reinforcement density, the procedure should assure that in Condition 2 the schedule on the right is associated with higher reinforcement density.

The present investigation was initiated with the purpose of testing the effect of order of experimental conditions on the sensitivity of behavior ratios to reinforcement ratios. An "inadequate" sequence of pairs of concurrent variable-interval, variable-interval (conc VI VI) schedules was chosen so to increase the chances of obtaining undermatching (according to de Villiers, 1977).

METHOD

Subjects

Three male, adult, experimentally naive pigeons, served. Birds were kept at aproximately 80% of their *ad lib* weights.

Apparatus

An experimental chamber for studies of operant behavior of pigeons, measuring 25 (frontal width) X 13 (rear width) X 29 (length) X 33 cm (height), was used. It consisted of a trapezoidal aluminum cage with three keys for use with rear projection systems. The keys could be operated by a force of 0.1 N or more. Located in a sound-proof room, the aluminum cage was enclosed in a chamber that attenuated most extraneous sounds. In a separate room, standard electromechanical programming and recording equipment monitored the experimental chamber.

Procedure

The central response key was illuminated by a yellow light (changeover key). The right key could be illuminated by a blue light, the left key by a red light (main keys). Pecks at the changeover key controlled which side was lit. A 3-s changeover delay (COD; Herrnstein, 1961) was in effect after each switching response. Attached to a wall of the enclosing chamber, a house light was lit during the experiment.

After shaping, subjects were exposed to the first experimental condition. A VI 60-s schedule was associated with the right/blue key, a VI 240-s schedule was associated with the left/red key. In successive experimental conditions, the VI schedule associated with the left/red key was varied to 180, 300, 360, 90, 60, and 15 s, while VI 60 s was always associated with the right/blue key.

Reinforcements were a 5-s period of access to food (triturated corn). Sessions ended after 60 reinforcements. A minimum of 23 sessions were conducted before changes in experimental conditions. The criterion for change depended upon the absence of trends in relative response rates on the last five sessions in any condition.

RESULTS

Table 1 gives the sums of raw data of the last five sessions in each condition. Figure 1 shows the logarithm response ratios as a function of the logarithm of reinforcement ratios (data from Table 1). For all three birds, the exponent of Equation 3 is close to 1.0 (slope in Figure 1); two birds show bias (k in Equation 3; intercept in Figure 1) in favor of the constant VI 60-s schedule (right/blue key), one pigeon shows bias toward the left/red key.

Figure 2 shows the logarithm of time ratios as a function of the logarithm of reinforcement ratios. The data from pigeon P39 show overmatching of time ratios to reinforcement ratios (exponent higher than 1.0 in Equation 4) and bias toward the right/blue key; the data from bird P40 show undermatching and bias toward the left/red key. Matching of time ratios to reinforcement ratios, and bias toward the left/red key, were observed for data from P41.

DISCUSSION

Previous interpretations of the role of order of experimental conditions in concurrent schedules (Baum, 1974; 1979; de Villiers, 1977) would predict low sensitivity of behavior ratios to reinforcement ratios in the data from the present experiment (exponent values in Equations 3 and 4 lower than 1.0). However, matching of response ratios to reinforcement ratios was observed for all three subjects, and exponents referring to time ratios show overmatching, matching and undermatching. Such results, consistent with those found in the literature (*e. g.*, Baum, 1979; Taylor & Davison, 1983; Todorov *et al.*, 1983; Wearden & Burgess, 1983) were obtained with a constant VI associated with the right/blue key and relatively small changes in obtained reinforcement rates in the left/red key in the first four experimental condi-

Table 1

The numbers of responses emitted, seconds spent responding, reinforcement obtained, changeovers, and sessions, per experimental condition. The data are sums of the last five sessions in each condition

Cond.	Responses		Time		Reinf.		CO	Sessions
	Blue	Red	Blue	Red	Blue	Red		
				P39				
1	10794	1836	11833	2567	239	61	377	30
2	14851	2544	10556	2945	229	71	424	28
3	19612	2342	16898	1926	253	47	382	30
4	17740	1662	12045	1916	260	40	348	29
5	7005	1139	8807	6485	203	97	182	30
6	5797	4556	3929	6813	139	161	366	30
				P40				
1	7772	1457	12048	1710	237	63	443	30
2	10994	1806	11381	1770	227	73	467	29
3	10273	616	15168	904	268	32	191	30
4	8873	1381	14038	1639	256	44	371	30
5	8657	1387	11476	2165	220	80	318	30
6	4714	2982	7082	3867	170	130	270	30
7	1951	2668	3209	2452	93	207	291	30
				P41				
1	5975	2253	12560	1686	235	65	564	30
2	8100	2539	11937	1285	227	73	400	30
3	8300	2177	12625	1679	246	54	412	23
4	9326	2815	13510	1936	254	46	519	30
5	6147	5250	6992	4200	186	114	988	30
6	3606	3410	5941	4191	155	145	534	30
7	505	3368	1663	3698	55	245	178	27

tions. Present data show that a given order of experimental conditions is not a necessary condition for matching of behavior ratios to reinforcement ratios.

Bias toward the right/blue key occurred in response data from bird P41 and in time data from bird P39; bias toward the left/red key occurred in response data from birds P39 and P40, and in time data from birds P40 and P41. Present results indicate no systemmatic effect of order of experimental conditions on bias.

This paper is a refutation of an assertion found in the literature (e. g., Baum, 1974;1979; de Villiers, 1977) concerning the effect of order of schedule pairs on exponent values. We do show that the ascribed order is not necessary condition for matching. Though other experimental procedures

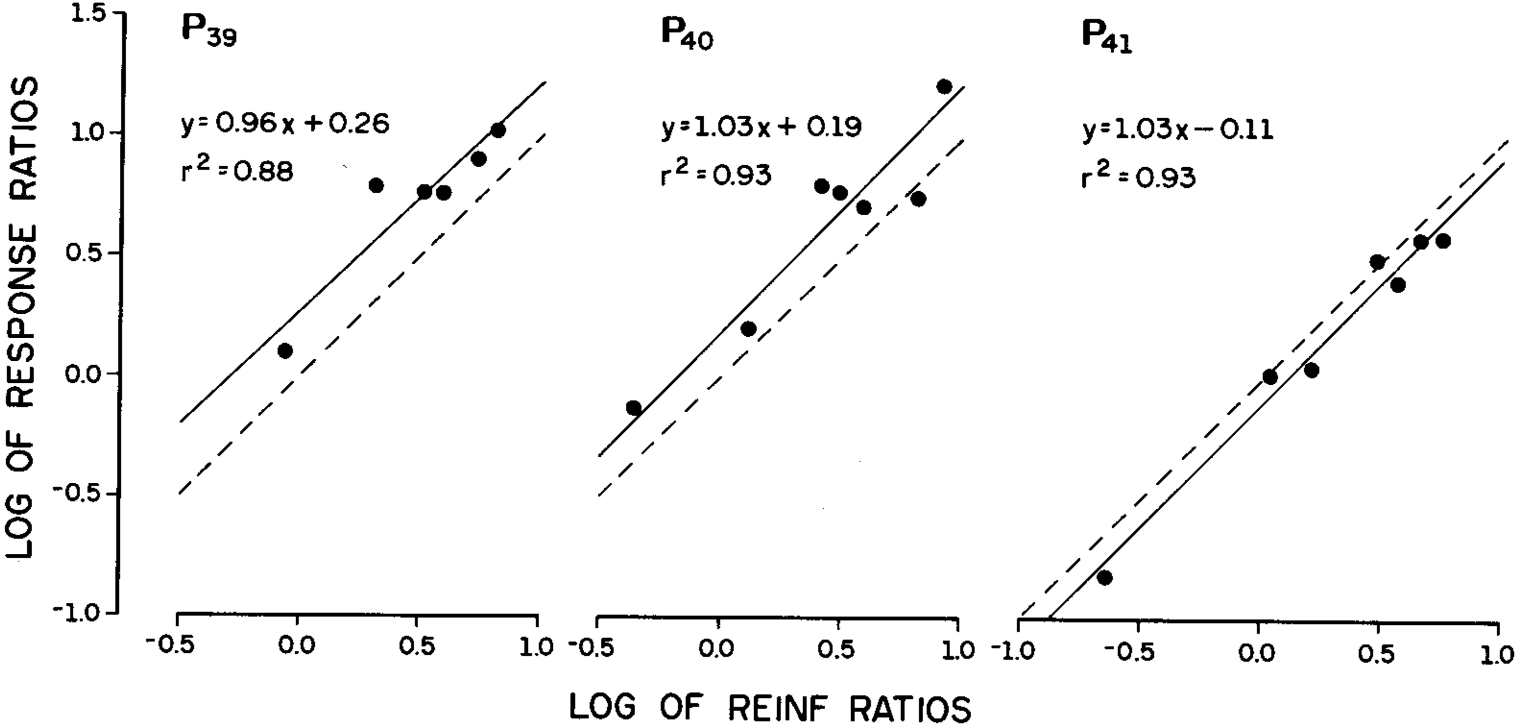

Fig. 1. Logarithm of response ratios as a function of logarithm of obtained reinforcement ratios.

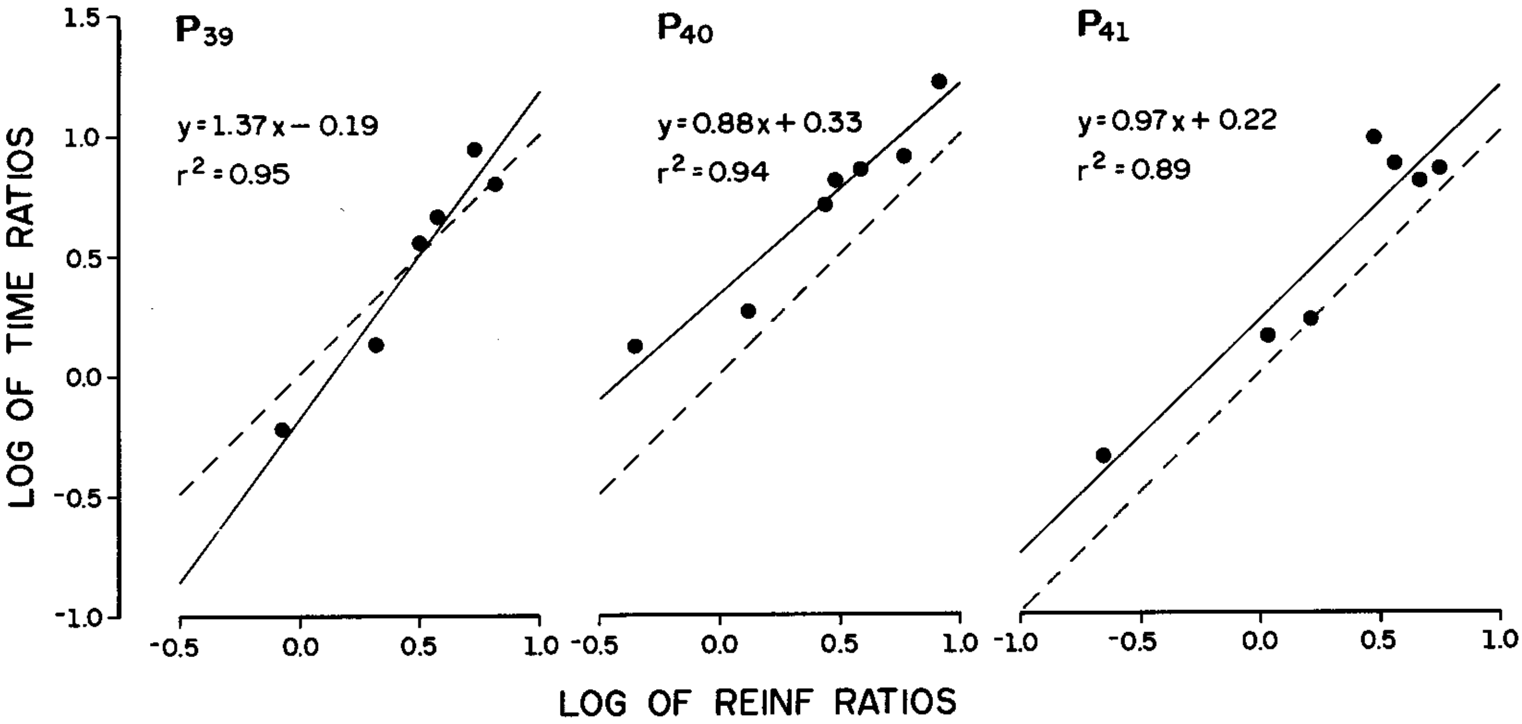

Fig. 2. Logarithm of time ratios as a function of logarithm of obtained reinforcement ratios.

would be necessary to investigate systematically the effect of order of schedule pairs on bias, to refute, empirically, an empirical statement found in the literature is a legitimate way of doing research.

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