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Concurrent second-order schedules of reinforcement: Relative response requirement.

Programas de reforzamiento concurrentes de segundo orden: Requerimiento relativo de respuesta

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ABSTRACT

Three pigeons were submitted to concurrent variable-interval (fixed-ratio), variable-interval (fixed-ratio) second-order schedules in which programmed reinforcement rate was the same for both alternatives, and ratio requirement was systematically varied. For data analysis, each completion of a ratio was considered as one response. The relationship between response ratios and ratios of response requirement was well described by a power function, with exponents similar to those reported by Beautrais and Davison (1977).

DESCRIPTORS: Second-order schedules, concurrent schedules, variable interval, fixed ratio, response requirement, pecking, pigeons.

RESUMEN

Tres pichones fueron expuestos a programas de segundo orden concurrentes intervalo-variable (razón fija), intervalo-variable (razón fija), en los que la tasa de reforzamiento programada era la misma para ambas alternativas, y se varió sistemáticamente el requerimiento de razón. Para el análisis de los datos, cada completamiento de una razón fue considerada como una respuesta. La relación entre tasas de respuesta y tasas de requerimiento de respuesta fue bien descrita por una función de poder, con exponentes similares a los reportados por Beautrais y Davison (1977).

DESCRIPTORES: programa de segundo orden, programas concurrentes, intervalo variable, razón fija, requerimiento de respuesta, picoteo, pichones.

The systematic investigation of performance maintained by concurrent schedules of reinforcement has attracted the attention of an increasing number of researchers in the last two decades. The data collected led to general

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theoretical propositions referring to the quantification of the law of effect (Herrnstein, 1970; de Villiers and Herrnstein, 1976; de Villiers, 1977). In concurrent schedules, performance is described by the power function

$$\frac{R_1}{R_2} = a \frac{X_1}{X_2}^{b} \tag{1}$$

where *R* represents responses and *X* is some parameter of reinforcement, as frequency, magnitude or immediacy. Subscripts refer to component schedules of the concurrent pair, and *a* and *b* are empirically determined. The parameter *a* measures systematic bias toward one schedule, and *b* is a measure of the sensitivity of performance to changes in the parameter *X* of reinforcement (Baum, 1974; Staddon, 1968, 1972).

In general, research on concurrent schedules deals with operants equivalent in topography and force required to activate microswitches responsible for the monitoring of response occurence. Usually a response is arbitrarily defined, when pigeons are subjects, as a peck with a minimum force of 0.1 N. Pecks which meet this requirement produce clear feedback such as clicks or flickering of the response-key light. However, operants may be defined as any feature of behavior on which reinforcement can be made contingent (cf. Schick, 1971; Shettleworth, 1974). In the present investigation, responses were defined as a number x of pecks, and feedback was provided in the form of a 1-sec period of lights off on the response key, characterizing the procedure as concurrent second-order schedules (Kelleher, 1966). The effects of relative response requirement on concurrent performances were investigated by systematically varying the required number of pecks defining the concurrent operants, in a partial replication of an experiment reported by Beautrais and Davison (1977).

METHOD

Subjects

Three male, adult pigeons, from uncontrolled derivations of the species Columba *livia,* caught wild, were used. The birds were maintained at approximately 80% of their free-feeding weight, and had water continuously available in their individual home cages.

Apparatus

A standard chamber for operant conditioning studies with pigeons, with two response-keys (Grason-Stadler, model 1121) was used. The right response key could be transilluminated by a red or green light; the left key, by a white light. A minimun force of 0.1 N was required to operate microswitches behind each key. Standard electromechanical equipment, located on a separate room, automatically programmed and recorded events. Reinforcement was a 5-sec period of access to grain.

Procedure

After shaping through differential reinforcement of successive approximations to key pecking, subjects were exposed to concurrent variable-interval (fixed-ratio), variable-interval (fixed-ratio) schedules (conc VI (FR) VI (FR). Both VI schedules were arranged on the right key (main key), each associated with a different exteroceptive stimulus. Every *n*th peck on the main key would produce a 1-sec timeout period, during which both response keys were dark and inoperative. At the end of this timeout period, both keys would be lighted and operative; the first peck on the main key would turn the left key (changeover key) dark and inoperative. If the first peck was at the changeover key that peck would (*a*) change the color on the main key and the schedule associated with that color, and (*b*) turn the changeover key dark and inoperative.

Throughout the experiment, equal VI 2-min schedules, independently programmed, were associated with both key colors. A scheduled reinforcement would be delivered after the *n*th peck on the key-color associated with that schedule. The numbers of pecks defining the concurrent operants where systematically varied in different experimental conditions (Table 1). No changeover delay was in force after a response on the changeover key, nor after main-key responses.

Daily sessions had a duration of 45 min. A minimum of 14 sessions per experimental condition were run before change in condition was considered. Responding was considered stable when no ascending or descending trends in response ratios occurred in the last five sessions.

RESULTS

Table 1 presents a summary of results from the last five sessions in each experimental condition. The data on response ratios (R_g/R_r) refer to numbers of responses as defined in this investigation (FR_g/FR_r), not to frequency of key pecks. Requirement ratios (w_r/w_g) were computed dividing requirement on red key-color by requirement on green key-color to have a direct function with response ratios.

The left side of Table 2 shows, for each bird, the constants *a* and *b* of the power function [$R_g/R_r = a(w_s/w_r)^b$] which best fit each set of data. For subjects 182 and 187, the slopeof the function (*b*) when logarithmic transformation of the data was used was close to 1.00, indicating that

Table 1

Responde requirement on concurrent schedules, number of sessions, and ratios of responses, obtained reinforcement and response requirements.

Fixed Green	Ratio Red	Sessions	R_g/R_r	r_g/r_r	w_2/w_g
		Bird 182			
10	10	25	1.13	0.98	1.00
4	16	21	4.79	1.01	4.00
16	4	19	0.25	1.00	0.25
7	13	31	1.61	1.07	1.86
13	7	23	0 45	0.95	0.54
6	14	25	2.69	1.06	2.33
		Bird 185			
10	10	21	1.39	1.07	1.00
4	16	21	1.39	0.86	4.00
16	4	20	0.63	1.05	0.25
7	13	31	1.20	1.03	1.86
13	7	23	0.83	0.95	0.54
6	14	24	1.21	0.84	2.33
		Bird 187			
10	10	23	0.99	1.01	1.00
4	16	21	3.57	0.96	4.00
16	4	18	0.27	0.96	0.25
7	13	29	1.06	1.03	1.86
13	7	20	0.28	0.94	0.54
6	14	24	1.34	0.95	2.33

response ratios approximately matched relative response requirement. The constant *a* indicates that there was no bias toward one of the key-colors for bird 182, while the data from subject 187 show strong bias in favor of the red key-color ($a = 0.75$). The coefficients of determination (r^2) for these birds show that the best fit power function accounted for 98% (bird 182) and 90% (bird 187) of the variance. Results from subject 185 show that ratios of response requirement had only a small effect on response ratios ($b = 0.28$), there was no bias toward one of the key color ($a = 1.03$), but the best fitting power function accounted for only 77% of the variance.

Table 2

Constants and coeficient of determination of the best fitting power function for the data of each subject

Birds	$R_g/R_r = a(w_r/w_g)^b$			$(R_g/R_r)/(r_g/r_r = a(w_r/w_g)^b$		
	a	b	r^2	a	b	r^2
182	1.01	1.07	0.98	1.00	1.05	0.98
185	1.03	0.28	0.77	1.06	0.34	0.90
187	0.75	0.92	0.90	0.77	0.91	0.91

Variations in obtained reinforcement ratios were considered on the right side of Table 2. Responses per obtained reinforcement on the green key-color (R_g/r_g) were divided by responses per obtained reinforcement on the red key-color (R_r/r_r). This correction for obtained reintforcement ratios did not change much the constants and the coefficient of determination of the power function for subjects 182 and 187, but improved the fitting for the data from subject 185. When deviations in scheduled reinforcement were considered, the function accounted for 90°/o or more of the variance in the data from all three birds.

DISCUSSION

The present data confirm and extend the findings of Beautrais and Davison (1977) on the effects of relative response requirement on performance maintained by concurrent second-order schedules of reinforcement. Beautrais and Davison used a two-key procedure of concurrent scheduling (Skinner, 1950), unequal variable-interval schedules, and varied response requirement from 2 to 10 pecks. In the present experiment a changeover key procedure (Findley, 1958), equal VI 2-min schedules, and response requirements from 4 to 16 pecks were used. In Beautrais and Davison's the feedback after a sequence of pecks consisted of turning key-lights off and the food magazine light on for 0.2 sec; in the present case, feedback was only a period of one second of key-ligths off and inoperative. In spite of such differences in procedure, the constants of the best fitting power function were similar. The values of the exponent in Equation 1 varied from 0.89 to 0.98 for five subjects, with a sixth subject providing a value of *b* equal to 0.49; a value of 0.85 was found for grouped data of six birds.

A reanalysis of data reported by Bacotti (1977), on concurrent variable-interval, fixed ratio (con VI FR) schedules, show that the sensibility of behavior to response requirement may be measured even in traditional schedules when programmed concurrently. Conc VI FR can be seen as second—order schedules, concurrent variable-interval (fixed-ratio 1), fixed-ratio 1 (fixed-ratio *n*) or conc VI (FR 1) FR 1 (FR *n*). In this sense since Bacotti reports that once responding on the ratio schedule subjects almost never switched over to the other schedule before completion of the ratio, his data were reanalyzed to verify how they would fit the equation

$$R_1/R_2 = a(r_1/r_2)^b (w_2/w_1)^c \tag{2}$$

where R denotes frenquency of responses (as defined above, (FR 1 or Fr *n*), *r* and *w* refer to obtained reinforcement frenquency and response requirement, respectively; *a, b,* and *c* are empirical constants, measuring bias, sensitivity to relative reinforcements frenquency, and sensitivity to relative response requirement. Utilizing a natural logarithm transformation, Equation 2 becomes

$$\log(R_1/R_2) = \log a + b \log(r_1/r_2) + c \log(w_2/w_1) \tag{3}$$

On the assumption of a linear combanation of the transformed variables, the multiple regression technique was used to compute the values of constants *a, b,* and *c*. Table 3 presents the constants and the percentage of the variance explained by the best fitting equation for the data of each subject utilized in the experiment, based on data presented on Table 2, Bacotti's (1977) report; between parenthesis are values obatined by Bacotti when the data were analyzed considering every peck as one response and utilizing Equation 1. Table 3 shows that the values referring to the sensitivity of behavior to

TABLE 3

Constants and coefficient of determination of the best fitting equation for the data of each subject in Bacotti's (1977) experiment. Numbers in parenthesis refer to values obtained by Bacotti using Equation 1 and considering every peck as one response.

$$R_1/R_2 = a(r_1/r_2)^b (w_2/w_1)^c$$

Subjects	a	b	c	r^2
50K	63.74 (1.46)	1.28 (1.11)	0.23	0.96
51K	0.02 (1.51)	0.81 (1.09)	2.14	0.97
52K	1.76 (1.30)	1.16 (1.13)	1.01	0.98
53K	28.40 (1.68)	1.35 (1.16)	0.56	0.96

relative reinforcement frequency (*b* in Equations 1 and 2) were only slightly different when relative response requirement was considered in the equation. On Bacotti's analysis, all subjects showed bias toward the VI schedule (*a* greater than 1.00); in Equation 2 one of the subjects show bias toward the FR schedule. The values of c show that subjects varied as to the sensitivity of behavior to relative response requirement. Two subjects show low sensitivity, like Beautrais and Davison's (1977) subject 185 and subject 185 in the present experiment; one subject shows high sensitivity ($a = 2.14$) to response requirement, and one provided data close to those obtained from four subjects in Beautrais and Davison's experiment and two subjects from the present investigation.

Considered together, the data reported by Beautrais and Davidon (1977), and from the present experiment, suggest that, although variability in measures of the sensitivity of behavior to relative response requirement is likely to occur among subjects, a value close to 1.00 may be expected for most subjects.

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