Revista Mexicana de Análisis de la Conducta,
1978, Vol. 4, Núm. 1, págs. 17-28.

Minimum interchangeover intervals in concurrent schedules

Intervalos de Cambio Mínimo en Programas Concurrentes[1]

Joao Claudio Todorov

Universidad Nacional Autónoma de México,
Universidade de Brasilia

Deisy das Gracas de Souza

Universidade Federal de Sao Carlos

ABSTRACT

Key pecking by pigeons was maintained by concurrent Variable interval-Variable interval schedules of reinforcement, under several values of minimum interchangeover interval. When the minimum interchangeover interval was signalled, relative response rate associated with the schedule providing higher frequency of reinforcement decreased with increases in that minimum interval, for two out of three birds. When the minimum interchangeover interval was unsignalled, relative rates of responding tended to match relative rates of reinforcement as that minimum interval was increased. also for two out of three birds.

DESCRIPTORS: concurrent schedules, minimum interchangeover, interchangeover, matching law, pigeons.

RESUMEN

Se mantuvo el picoteo de pichones sobre una tecla con programas de reforzamiento concurrentes Intervalo variable-Intervalo variable, bajo diferentes valores de un intervalo de cambio mínimo. Cuando se señaló el intervalo mínimo de cambio, la tasa de respuesta relativa asociada al programa que proporcionaba una frecuencia mayor de reforzamiento se decrementó con incrementos en ese intervalo mínimo para dos de tres pichones. Cuando no se señaló el intervalo mínimo de cambio, las tasas de respuesta relativas tendieron a igualar a las tasas relativas de reforzamiento conforme se incrementaba el intervalo mínimo, también para dos de tres pichones.

DESCRIPTORES: programas concurrentes, intervalo de cambio, demora en el cambio, ley de igualación, pichones.

[1] Reprints may be obtained from J. C. Todorov, Apartado Postal 69-716, México 21, D. F. México.

In concurrent variable-interval, variable-interval (conc VI VI) schedules, different responses are associated with two schedules, each schedule independently programming reinforcements for its associated response. The relationship between the relative rate of responding associated with a schedule and the relative frequency of reinforcements provided by that schedule has been extensively investigated (cf. Catania, 1966; de Villiers, 1977; Herrnstein, 1970, 1974; Todorov, 1974, 1977). The data generated by such investigations called the attention of researchers to relationships between relative performance and relative parameters of reinforcement in other schedules, and led to a general theoretical formulation of a quantitative law of effect, or a law of response strength (Herrnstein, 1970; de Villiers and Herrnstein, 1976)

$$R_1 = kr_1 / r_i \qquad (1)$$

where *R* and *r* are frequencies of responses and reinforcements, respectively, per unit of time, *k* is a constant of proporcionality characteristic of R_1, and the denominator includes all reinforcement being obtained in that unit of time. If both concurrent operants in conc VI VI schedules have the same topography and involve the same amount of effort, the value of *k* in equation 1 should be the same both for R_1 and R_2, and the relationship between relative rate of responding and relative rate of reinforcement should be described by the following equation:

$$R_1 / (R_1 + R_2) = r_1 / (r_1 + r_2) \qquad (2)$$

where the subscripts denote component schedules.

Data from experiments on conc VI VI show that the relationship between relative rate of responding and relative rate of reinforcement usually is close to the matching predicted by equation 2, under certain circumstances. Herrnstein (1961) found it necessary to use a changeover delay (COD) to separate in time responding in one schedule from reinforcement in the second schedule. A COD specifies a minimun time between responses in one schedule and the possibility of a reinforcement following responses in the second schedule. With no COD following changeovers, relative response rates undermatch relative reinforcement rates, although an orderly function is obtained when relative reinforcement is manipulated (Todorov, 1971, Exp. II). Increases in COD duration are followed by increases in relative response rates, and, after some minimum COD value, relative responding approximately matches relative rate of *obtained* reinforcement, which at long COD durations may be different from the rate of scheduled reinforcement.

The role of the COD in the matching relationship is yet unclear. Catania (1966) suggested that its function was to avoid concurrent superstition, i.e., responses in one schedule being maintained by reinforcements provided by the other schedule. Pliskoff (1971) and Todorov (1969, 1971) interpreted the function of a COD as punishment of changeovers, since changeover rate systematically decreases with increases in COD duration (cf. Shull and Pliskoff, 1967; Stubbs and Pliskoff, 1969). Explicit punishment of changeovers by response cost (Stubbs and Pliskoff, 1969), brief shock (Todorov, 1971), or timeout (Todorov, 1971, 1973), however, may result in overmatching: relative response rate increases with decreases in changeover rate, while relative rate of obtained reinforcement practically does not change.

The purpose of the present experiment was to investigate the effects on relative rate of responding in conc VI VI of a different variable, a minimum interchangeover interval (MII). An MII establishes that once a changeover between schedules occurs, another changeover cannot occur for the duration of the MII. Unlike a COD, an MII does not prevent responding in one schedule from being followed closely in time by reinforcement provided by the other schedule; like a COD, it should increase the average number of consecutive responses in a schedule before a changeover.

METHOD

Subjects

Six male adult, experimentally naive pigeons, from uncontrolled derivations of the species Columba *livia,* caught wild, were used. The subjects were maintained at about 80% of their body weight, determined during a period of free access to food.

Apparatus

A standard chamber for operant conditioning studies with pigeons, with three response-keys, was used. The right response-key was transilluminated by a red light, the center key by a green light; the left response-key was always dark and unoperative. The chamber was illuminated from the beginning to the end of experimental sessions by a houselight located on the upper left corner of the panel. During reinforcements (presentation of grain), the houselight and response-key lights were turned off, and the opening was illuminated.

Procedure

The two-key procedure for concurrent scheduling (cf. Catania, 1966) was used. VI 1-min was associated with the right response-key (red) and VI 3-min with the center key (green). Changeovers (pecks on one key following pecks on the other key) would initiate periods (minimum interchangeover intervals) during which reinforcements could be obtained only on that response key. Changing back during this MII would initiate another MII on the second key, so that frequent changeovers during the MII would result in long sequences of unreinforced responses.

For subjects SGI, SG-2, and SG-3, the MII was signalled; the last pecked response-key before a changeover, was off for the duration of the MII (group Signalled). For subjects NS-4, NS-5, and NS-6, both keys remained illuminated during the MII, and no exteroceptive stimulus signalled when pecks at either key could or could not be reinforced (group Unsignalled). The COD procedure was not used.

The duration of the MII was manipulated, and the resulting changes in the following variables were investigated:

a) The relative rate of responses in the red key (VI 1-min), i.e., $R_1/(R_1 + R_2)$.

b) The relative rate of reinforcements obtained in the red key, i.e., $r_1/(r_1 + r_2)$.

c) The proportion of responses occurring in a schedule after the MII relative to the total number of responses in that schedule, i.e., $R_A/(R_A + R_i)$, where R_A represents responses after the end of a given MII and R_i are responses occurring during that interval.

d) The absolute rates of responding in each schedule, i.e., responses in each schedule divided by session time, or R_1/T and R_2/T.

All experimental conditions were arranged through electromechanical circuitry. Experimental sessions ended after the sixtieth reinforcement. At least 14 daily sessions were conducted under each experimental condition. When relative response rates revealed no ascending or descending trends over the last five sessions, another experimental condition was introduced. The number of sessions per condition for each subject is shown in Table 1.

RESULTS

Data from the last five sessions in every experimental condition are presented in Table 1. Figure 1 shows the difference between relative rates of responding and of obtained reinforcements as a function of MII length, for subjects SG-2 and SG-3, group Signalled. The data from suject SG-1 are not included, since this subject showed a strong bias toward the red key, which was not affected by variations in MII duration (see Table 1). For subjects SG-2 and SG-3, relative response rates tended to match relative rates of obtained reinforcements at short values of the MII. Deviation from matching increased in the direction of undermatching as the MII duration increased.

The effects of changes in MII length on the relationship between relative rates of responses and reinforcements, for subjects of the group Unsignalled, are shown in Figure 2. For subject NS-4, increasing MII length

TABLE 1

Data from the last five sessions of each experimental condition, for each subject in the Signalled group (SG-1, SG-2, SG-3) and in the Unsignalled group (NS-4, NS-5, NS-6). Values of the minimum interchangeover interval (MII) appear in the first column, in the order the experimental conditions were arranged.

MII		Absolute Resp Rates (R/min)		Rel Resp Rate	Rel Reinf Rate	Proportion Resp After MII	
		VI 1	VI 3	VI 1	VI 1	VI 1	VI 3
				SG-1			
2	115	17	10	0.63	0.73	0.38	0.11
10	25	14	3	0.81	0.74	0.08	0.14
50	26	16	1	0.97	0.80	0.54	0.00
100	30	17	1	0.93	0.76	0.28	0.00
200	14	17	2	0.92	0.72	0.20	0.00
30	14	16	1	0.96	0.75	0.49	0.00
20	24	18	1	0.94	0.75	0.32	0.00
2	16	19	1	0.94	0.75	0.90	0.32
10	27	18	1	0.94	0.75	0.32	0.23
				SG-2			
2	86	45	20	0.70	0.73	0.42	0.19
10	17	37	26	0.60	0.73	0.20	0.04
30	22	38	27	0.60	0.71	0.02	0.01
100	24	36	34	0.52	0.68	0.00	0.00
200	16	42	36	0.53	0.70	0.00	0.00
50	19	39	37	0.51	0.71	0.01	0.00
20	26	36	30	0.55	0.70	0.02	0.01
2	21	40	41	0.50	0.73	0.29	0.09
30	16	43	31	0.59	0.72	0.01	0.01
10	17	39	35	0.57	0.73	0.05	0.06
20	24	39	30	0.57	0.72	0.02	0.02
				SG-3			
2	45	29	10	0.74	0.72	0.17	0.39
10	18	23	8	0.74	0.74	0.30	0.29
30	18	22	13	0.64	0.72	0.01	0.03
50	36	23	14	0.61	0.71	0.01	0.01
100	15	22	13	0.61	0.70	0.00	0.02
200	35	22	19	0.57	0.67	0.00	0.00
20	17	22	18	0.57	0.69	0.03	0.03
2	34	30	11	0.72	0.73	0.18	0.10
10	24	22	8	0.74	0.72	0.06	0.07

Tabla 1 (*continuación*)

			SG-4				
2	53	22	14	0.62	0.73	0.39	0.27
10	25	20	15	0.58	0.73	0.13	0.09
50	18	17	14	0.57	0.72	0.04	0.02
100	63	16	9	0.63	0.70	0.04	0.03
200	29	24	12	0.66	0.70	0.00	0.01
30	31	18	11	0.63	0.71	0.09	0.02
20	21	17	10	0.62	0.73	0.20	0.04
			SG-5				
2	51	25	8	0.74	0.73	0.51	0.18
10	14	25	9	0.73	0.73	0.23	0.07
30	19	24	10	0.70	0.72	0.21	0.07
50	46	20	6	0.78	0.71	0.07	0.03
100	15	13	6	0.70	0.69	0.03	0.04
200	15	15	7	0.69	0.65	0.02	0.01
20	18	19	5	0.80	0.73	0.21	0.07
2	14	23	4	0.85	0.74	0.77	0.09
30	23	19	5	0.81	0.72	0.17	0.10
10	15	17	7	0.70	0.72	0.25	0.07
			SG-6				
2	61	19	7	0.74	0.74	0.58	0.16
20	56	19	12	0.61	0.73	0.13	0.02
50	22	17	15	0.57	0.71	0.06	0.01
100	20	17	16	0.54	0.68	0.01	0.00
200	53	33	15	0.67	0.69	0.02	0.02

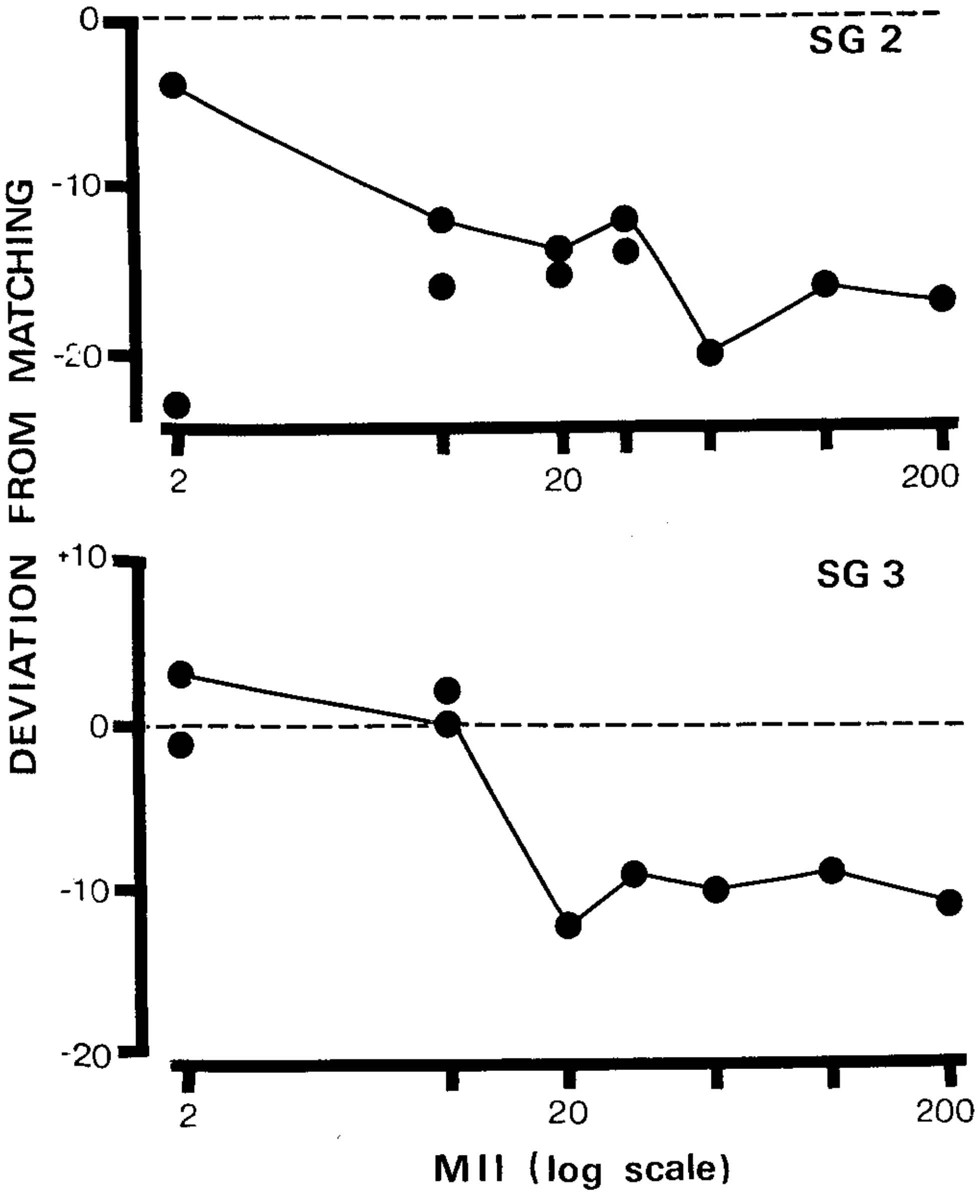

Fig. 1. Difference between relative rates of responding and relative rates of obtained reinforcements (deviation from matching) as a function of minimum interchangeover interval (MII) length in sec, for subjects SG-2 and SG-3, group Signalled.

resulted in decreasing differences between relative rate of responses and relative rate of reinforcements. Data from subject NS-5 show no systematic effect of MII length on the relationship between those relative measures; matching was obtained for most values of MII length, with variations occurring in the direction of overmatching. Data from subject NS-6 are not included in Figure 2, since its results are atypical: matching was obtained at MII values of 2 and 200 sec, and clear deviations in the direction of undermatching at 20, 50, and 100 sec (see Table 1).

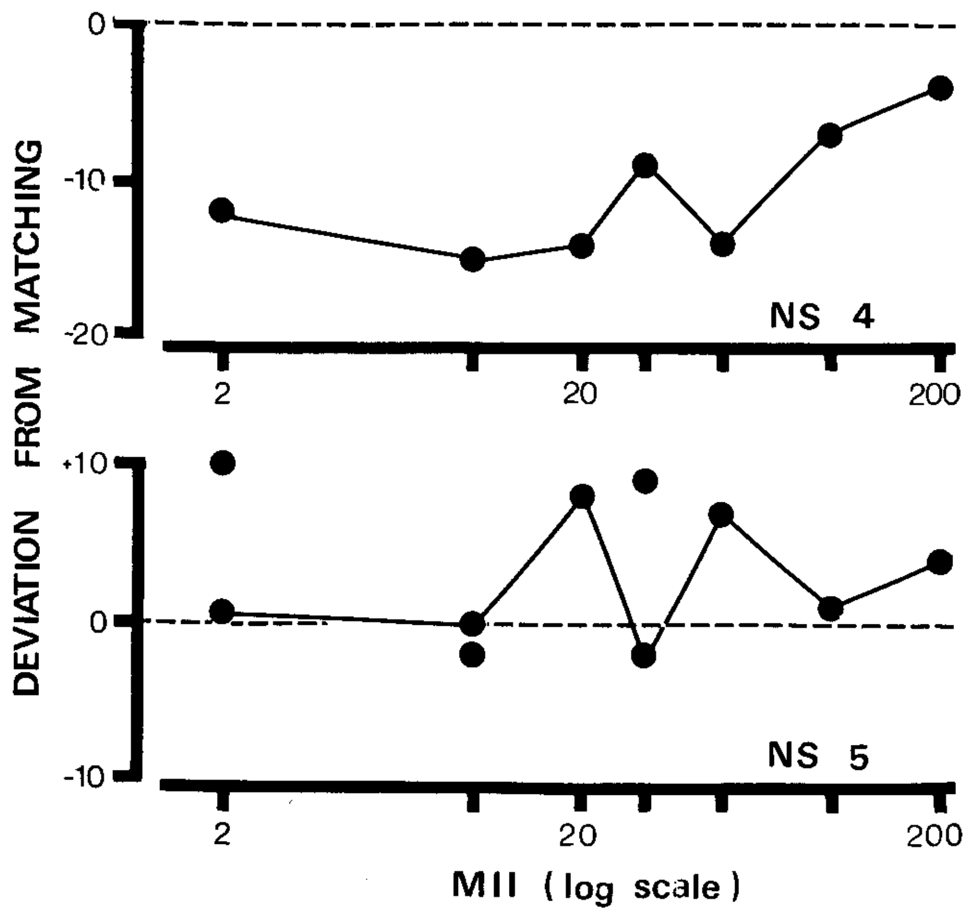

Fig. 2. Difference between relative rates of responding and relative rates of obtained reinforcements (deviation from matching) as a function of minimum interchangeover interval (MII) length in sec, for subjects NS-4 and NS-5, group Unsingnalled.

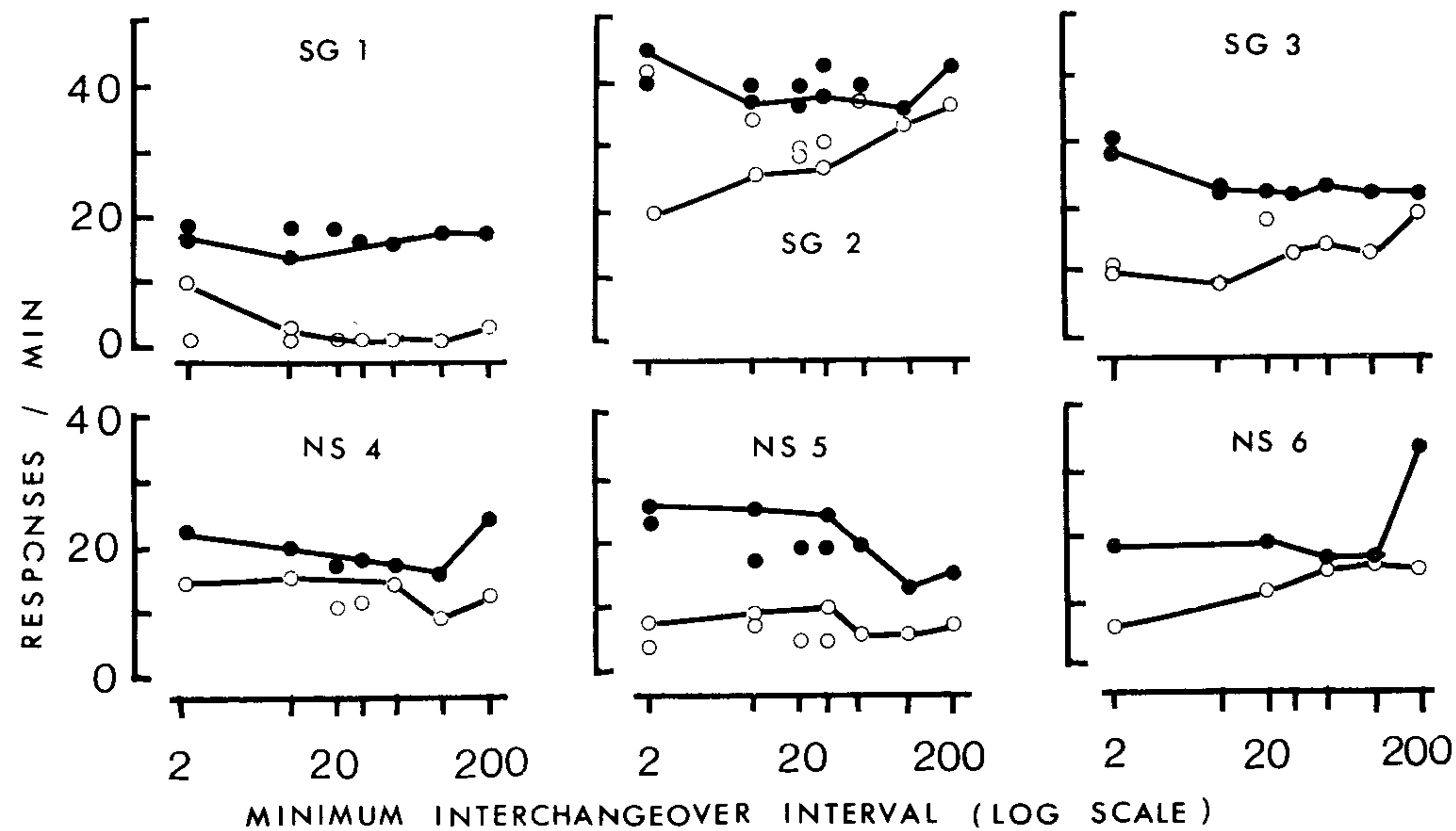

Fig. 3. Absolute response rates under VI 1-min (filled circles) and VI 3-min (unfilled circles) as a function of minimum interchangeover interval (MII) in sec for subjects on the Signalled group (upper graphs) and on the Unsignalled group (lower graphs).

Figure 3 shows the effects of MII length on absolute rates of responding under VI 1-min and VI 3-min. Again, data from SG-1 and NS-6 are atypical. For SG-1, response rate associated with VI 1-min did not change with changes in the MII, and responding under VI 3-min occurred at very low rates, except for the first experimental condition (MII 2 sec). For NS-6, responding under VI 1-min did not change, except for a considerable increase when the MII was changed from 100 to 200 sec. Responding under VI 3-min increased systematically as the MII was increased.

For subjects SG-2 and SG-3, group Signalled (Figure 3), responding under VI 1-min tended to decrease and responding under VI 3-min tended to increase as MII length was increased. For subjects NS-4 and NS-5, group Unsignalled, responding under VI 1-min also tended to decrease, while responding under VI 3-min did not change systematically, with increases in MII length.

The effect of signalling the MII are clearly seen in the data relative to the proportions of responses occurring in each schedule after the MII had elapsed (see Procedure). For both groups, responding after the MII tended to decrease with increases in the MII (Table 1), but for the group Signalled the decrease is more abrupt. Only for MII values of 2 and 10 sec those proportions were considerable (subjects SG-2 and SG-3). For the group Unsignalled, the decrease in proportions of responding after the MII is more smooth, with values associated with VI 1-min generally higher than those associated with VI 3-min.

DISCUSSION

The failure of two subjects, one in each group, to replicate the data obtained from the other animals complicates the interpretation of results. The procedure utilized could be modified so that the effects of variations in the minimum interchangeover interval may be clearly seen in the data from every subject. However, the data from four subjects, two in each group, are suggestive. For the group Signalled, the effects of changes in the MII are similar to the effects of changes in component duration in multiple VI VI schedules (Shimp and Wheatley, 1971; Todorov, 1972): relative response rates tend to match relative rates of obtained reinforcement at short interval values, absolute rates in VI 1-min tend to decrease and in VI 3-min tend to increase as the intervals are increased (cf. de Villiers, 1977).

Data from the group Unsignalled are similar to what is obtained when COD lenght is varied in conc VI VI: increasing the interval length affects relative response rate when that relative measure is lower than the ıelative rate of obtained reinforcement (undermatching). When matching of relative rates of responding and reinforcement is reached, further increases in interval length do not affect the relationship betwwen those relative measures (Shull and Pliskoff, 1967).

The effects observed when the MII was signalled can be understood in terms of the contingencies programmed. The higher the duration of a MII, the greater the probability that a reinforcement would be set up by the other schedule while the MII was in force. Thus at the moment in which the light was on again on the other response-key, the probability of reinforcement on that key was higher than the probability on the key in which the subject was responding during the MII. This difference in probability tended to increase with increases in MII length. Since change-overs occurred as soon as the MII ended, for most values of MII used, subjects actually were responding under multiple schedules, in spite of the formal definition and scheduling as conc VI VI.

The data from subjects NS-4 and NS-5 suggest that separation in time of responses in one schedule from reinforcements provided by the other schedule may not be necessary for matching to occur. The MII actually increases the probability that a changeover will be immediately followed by reinforcement. What the changeover delay and the minimum inter-changeover time procedures have in common is the induction of longer periods of responding in each schedule between changeovers, when compared to interchangeover times observed when no COD or MII is scheduled as a consequence of changeovers (cf. Stubbs, Pliskoff and Reid, 1977).

REFERENCES

Catania, A. C. Concurrent operants. In W. K. Honig (Ed.), *Operant behavior: areas of research and application.* N. York: Appleton-Century-Crofts, 1966. Pp. 213-270.

de Villiers, P. A. Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig and J. E. R. Staddon (Eds.), *Handbook of operant behavior.* Englewood Cliffs, N. J.: Prentice-Hall, 1977. Pp. 233-287.

de Villiers, P. A. and Herrnstein, R. J. Toward a law of response strength. *Psychological Bulletin,* 1976, 83, 1131-1153.

Herrnstein, R. J. Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior,* 1961, *4,* 267-272.

Herrnstein, R. J. On the law of effect. *Journal of the Experimental Analysis of Behavior,* 1970, 13, 243-266.

Herrnstein, R. J. Formal properties of the matching law. *Journal of the Experimental Analysis of Behavior,* 1974, 21, 159-164.

Pliskoff, S. S. Effects of symmetrical and asymmetrical changeover delay on concurrent performances. *Journal of the Experimental Analysis of Behavior,* 1971, *16,* 249-256.

Shimp, C. P. and Wheatley, K. L. Matching to relative reinforcement frequency in multiple schedules with a short component duration. *Journal of the Experimental Analysis of Behavior,* 1971, *15,* 205-210.

Shull, R. L. and Pliskoff, S. S. Changeover delay and concurrent schedules: some effects on relative performance measures. *Journal of the Experimental Analysis of Behavior,* 1967, *10,* 517-527.

Stubbs, D. A. and Pliskoff, S. S. Concurrent responding with fixed relative rate of reinforcement. *Journal of the Experimental Analysis of Behavior,* 1969, 12, 887-895.

Stubbs, D. A., Pliskoff, S. S., and Reid, H. M. Concurrent schedules: a quantitative relation between changeover behavior and its consequences. *Journal of the Experimental Analysis* of Behavior, 1977, 25, 85-96.

Todorov, J. C. *Some effects of punishment on concurrent performances.* Unpublished doctoral dissertation, Arizona State University, 1969.

Todorov, J. C. Concurrent performances: effect of punishment contingent on the switching responce. *Journal of the Experimental Analysis of Behavior,* 1971, *16,* 51-62.

Todorov, J. C. Component duration and relative response rates in multiple schedules. *Journal of the Experimental Analysis of Behavior,* 1972, *17,* 45-49.

Todorov, J. C. Interaction of frequency and magnitude of reinforcement on concurrent performance. *Journal of the Experimental Analysis of Behavior,* 1973, *19,* 451-458.

Todorov, J. C. Medidas relativas de la ejecución mantenida por programas de refuerzo. In R. Ardila (Ed.), *El análisis experimental del comportamiento: la contribución latinoamericana.* México: Trillas, 1974, Pp. 66-97.

Todorov, J. C. Sistematización de datos empíricos sin (o casi sin) el auxilio de una teoría. In P. Speller (Ed.), *Memorias del III Congreso Latinoamericano de Análisis de la Conducta.* México: Trillas, 1978.