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SECOND-ORDER SCHEDULES OF TOKEN REINFORCEMENT: EFFECTS OF VARYING THE SCHEDULE OF FOOD PRESENTATION[1]

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In the initial link of a complex schedule, one discriminative stimulus was presented and lever pressing produced tokens on fixed-ratio schedules. In the terminal link, signalled by a second discriminative stimulus, deposits of the tokens produced food. With two rats, the terminal link was presented after each sixth component schedule of token reinforcement was completed. With the other two rats, the terminal link was presented following the first component schedule completed after a fixed interval. During the terminal link, each token deposit initially produced food. The schedule of food presentation was subsequently increased such that an increasing number of token deposits in the terminal link was required for each food presentation. Rates of lever pressing in the initial link were inversely related to the schedule of food presentation in the terminal link. These results are similar to those of experiments that have varied schedules of food presentation in chained schedules. Rates and patterns of responding controlled throughout the initial link were more similar to those ordinarily controlled by second-order brief-stimulus schedules than to those controlled by comparable extended chained schedules.

Key words: second-order schedules, chained schedules, token reinforcement, reinforcement probability, lever press, rats

Second-order schedules involving brief-stimulus and chaining procedures have been widely studied (*cf.*, Kelleher, 1966; Marr, 1969; Stubbs, 1971). A third form of second-order schedule, involving delivery of tokens, has received less attention. This procedure may be described in terms of the three types of schedules inherent within the paradigm. The first is the schedule of token reinforcement: the schedule according to which a response (*e.g.*, lever pressing) produces delivery of tokens (objects such as poker chips or marbles). The second is the exchange schedule: the schedule for presenting a discriminative stimulus in the presence of which the tokens may be exchanged for food. The third is the schedule of food reinforcement: the schedule according to which token deposits produce food.

Previous experiments studying token reinforcement with chimpanzees (Kelleher, 1956; 1957*a, b, c;* 1958) and with rats (Malagodi, 1966; 1967*a, b, c;* Waddell, Leander, Webbe, and Malagodi, 1972) have examined lever pressing (or panel pushing) under several combinations of schedules of token reinforcement and exchange schedules. In general, the results reflected the contribution of both types of schedules in controlling characteristic patterns of responding throughout sequences of components terminating in token reinforcement. In those experiments, and in the early studies of Wolfe (1936) and Cowles (1937), the deposit of each token (in the presence of the appropriate discriminative stimulus) produced food delivery.

The present experiment followed Kelleher's (1956) suggestion that it would be interesting to determine the effects of "inflating the coin of the realm" in the token-reinforcement paradigm by increasing the number of token deposits required for delivery of each food reinforcer. The effects of this manipulation were of interest for two reasons. First, of the three types of schedules inherent within the paradigm, it is the only one that has not been studied experimentally. Second, experiments with chained schedules have shown that the schedule of food presentation in the terminal link is a powerful determinant of responding in antecedent links (*cf.*, Kelleher, 1966; Kelleher and Gollub, 1962, Marr, 1969). The effects of varying the schedule of food presentation would thus bear upon the analysis of the token-reinforcement paradigm as a form of extended chained schedule (Kelleher, 1966; Kelleher and

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Gollub, 1962). The forms of the schedules of token reinforcement and exchange schedules used in the present experiment were similar to those used previously in second-order brief-stimulus schedules. These aspects of the procedure enabled relating the results to suggestions that the token-reinforcement paradigm also resembles brief-stimulus procedures (Marr, 1969; Waddell *et al.*, 1972).

METHOD

Subjects

Four adult male Long-Evans hooded rats were maintained at 80% of their adjusted free-feeding weights; their 80% deprivation values were calculated weekly on the basis of the mean weights of free-feeding male littermates. They had free access to water in their home cages. Rats T-22 and T-23 were experimentally naive, and Rats W-33 and W-35 had served in a previous token-reinforcement experiment (Waddell *et al.*, 1972).

Apparatus

The experimental chamber contained a Gerbrand's rat lever, a hopper into which dark clear-glass marbles (tokens) were dispensed, a receptacle into which the rats deposited the marbles, and a hopper into which 45-mg Noyes standard-formula food pellets were dispensed. A red light (6-W, 115-V ac) was located directly above the lever and a similar white light was located inside the receptacle. The chamber was housed within a ventilated, sound-attenuating exterior chamber. A one-way window allowed for observation of the rats, and an exhaust fan, air-conditioner, and white-noise generator provided masking background noise. Standard electromechanical scheduling and recording equipment was located in an adjacent room. A detailed description of the experimental chamber and early training procedures has been presented elsewhere (Malagodi, 1967*a*).

Procedure

The initial condition for Rat T-22 illustrates the basic procedure, notation system, and use of descriptive terms such as "links" and "components". In the presence of the red light, each 20 lever presses produced delivery of a single token (FR 20: TOKEN), each delivery being accompanied by a 0.75-sec, 1000-Hz tone. Completion of six successive FR 20: TOKEN schedules turned off the red light and turned on the white light and a clicker (FR 6: EXCHANGE). Initially, in the presence of the white light and clicker, the deposit of each token into the receptacle produced a single food pellet (FR:1 FOOD). The white light and clicker terminated 0.75 sec after the last token was deposited, at which time the red light and corresponding schedule were re-instated. The red-light sequence is referred to as the *initial link,* the white-light/clicker sequence as the *terminal link.* The successive FR 20: TOKEN schedules during the initial link are referred to as *component schedules.* The initial condition was the same with Rat T-23, except that an FR 15: TOKEN schedule was used.

Rats W-33 and W-35 were exposed to similar conditions, except that the exchange schedule was fixed interval rather than fixed ratio. The schedule of token reinforcement for both rats was FR 20: TOKEN, and the first component schedule completed after a fixed period of time in the initial link resulted in presentation of the terminal link. The fixed-interval parameter of the exchange schedule was 4.5 min with Rat W-33 (FI 4.5: EXCHANGE), and 9.0 min with Rat W-35 (FI 9.0: EXCHANGE). These fixed-interval parameters were selected as those that produced comparable baseline performance for the two rats.

The baseline conditions remained in effect until both lever pressing and token depositing were stable. Stability was defined as the absence of any systematic trends in overall rates of level pressing and in rates within individual components for 10 consecutive sessions. In addition, medians and ranges of overall rates for the last five sessions had to be equivalent to those from the previous five sessions before conditions were changed. After stability had been obtained, the initial-link schedules were held constant while the schedule of food presentation in the terminal link was systematically varied. The schedule of food presentation was increased for all rats to FR 2: FOOD—delivery of one food pellet followed deposit of every second token. Thus, with Rats T-22 and T-23, the second, fourth, and sixth deposits during each presentation of the terminal link produced food. Because Rats W-33 and W-35 responded under FI *t:* EXCHANGE schedules, the number of tokens available for deposit varied in presentations of the terminal link, depending upon the number of component FR

20: TOKEN schedules completed during the preceding initial link. Thus, with these rats, the FR 2: FOOD schedule simply specified that every second deposit (during the white light and clicker) throughout the session produced food. With Rats W-33 and W-35, the schedule in the terminal link was subsequently increased to FR 4: FOOD. With Rats T-22 and T-23, the schedule in the terminal link was subsequently increased to FR 3: FOOD and to FR 6: FOOD, then increased further to FR 12: FOOD with Rat T-22. Under FR 12: FOOD, the sixth deposit during every other terminal link produced a food pellet. Second exposures were made to several of the FR *n:* FOOD schedules with three rats. The number of sessions at each value of the food schedule and the orders of exposure are shown in Table 1.

One rat, T-23, occasionally deposited a token during the initial link, no food being presented for such a response. When this occurred, the terminal link was still presented when the sixth FR 15: TOKEN schedule was completed, and (under FR 2: FOOD, for example) the second and fourth deposits produced food; the terminal link ended after the fifth and last token was deposited. The FR 2: FOOD schedule was then reset such that during the next presentation of the terminal link, the second, fourth, and sixth deposits each again produced a food pellet.

Experimental sessions were conducted six days per week. With Rats T-22 and T-23, sessions ended after the thirteenth terminal link was completed (after the fourteenth for Rat T-22 during FR 12: FOOD). With Rats W-33 and W-35, sessions ended following the first terminal link completed after a minimum of 2 hr total time in the initial link.

RESULTS

The mean rates of lever pressing for Rats T-22 and T-23 during the last five sessions at each value of the FR *n:* FOOD schedule are summarized in Figure 1. Shown are the overall response rates as well as those in each of the six successive component schedules of token reinforcement. Figure 2 shows representative cumulative records for Rat T-22 taken from the median of the last five sessions at several of the FR *n:* FOOD schedules. Those from Rat T-23 were essentially the same. Rat T-22 showed a monotonic decrease in overall rate of lever pressing during both series (Figure 1A and 1B, enclosed boxes). There was little change in overall rate with Rat T-23 until the schedule was increased to FR 6: FOOD (Figure 1C, enclosed box). The decrease in overall rate with Rat T-22 during the first series was due exclusively to a decrease in rate during the first FR 20: TOKEN component (Figure 1A); this rate decrease was primarily due to an increase in pausing at the beginning of each presentation of the initial link (Figure 2A). The decrease in overall rate with Rat T-22 during the second series, and with Rat T-23, was reflected by rate decreases in each succes-

Table 1

The Order of Experimental Conditions

		Number of Sessions			
	Token Schedule:	*Rat T-22* *FR 20*	*Rat T-23* *FR 15*	*Rat W-33* *FR 20*	*Rat W-35* *FR 20*
Food Schedule	*Exchange Schedule:*	*FR 6*	*FR 6*	*FI 4.5-min*	*FI 9.0-min*
First series					
FR 1		20	25	46	40
FR 2		14	27	39	16
FR 3		15	20		
FR 4				40	24
FR 6		11	20		
Second series					
FR 3		28			
FR 1		60		42	14
FR 2				14	
FR 4				28	27
FR 6		23			
FR 12		14			

sive FR *n:* TOKEN component (Figure 1B and 1C). These rate decreases within components were primarily characterized by increases in initial pausing in all components (Figure 2B and 2C).

During both series, at all values of the FR *n:* FOOD schedule, response rates were lowest for Rat T-22 during the first FR 20: TOKEN component, and were essentially constant from the second through the sixth components (Figures 1A, 1B, 2). With Rat T-23, there was a sharp increase in rate from the first to the second component, followed by a more gradual increase from the second through the fifth components (Figure 1C). In general, characteristic bivalued patterns of responding were maintained within individual FR *n:* TOKEN components with both rats. Under FR 12: FOOD with Rat T-22, there were no systematic differences in responding between initial links that preceded terminal links in which food was presented and those that preceded terminal links in which food was not presented (Figure 2C).

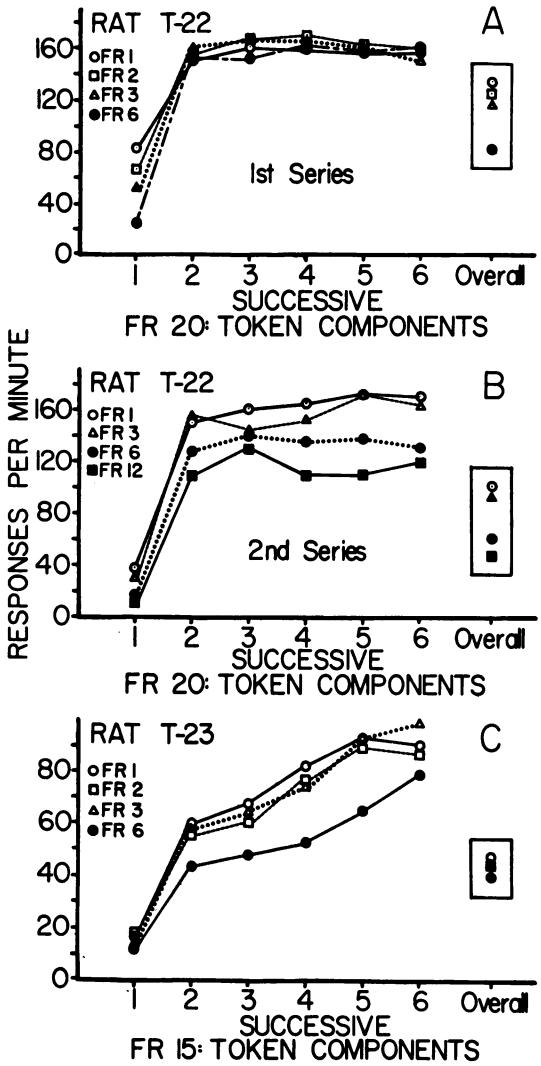

Fig. 1. Rates of lever pressing for Rats T-22 and T-23 at each value of the FR *n:* FOOD schedule. Shown are the mean response rates in each successive FR: TOKEN component, and mean overall response rates.

Figure 3 summarizes the mean rates of lever pressing for Rats W-33 and W-35 during the last five sessions at each value of the FR *n:* FOOD schedule. Shown are the overall response rates and those in successive tenths of the FI *t:* EXCHANGE schedules. Representative cumulative records at two FR *n:* FOOD schedules for Rat W-35 are displayed in Figure 4. Those from Rat W-33 were essentially the same. With both rats, overall rate of lever pressing, or rates within successive tenths of the fixed interval, were affected little by increasing the schedule in the terminal link from FR 1: FOOD to FR 2: FOOD. At FR 4: FOOD, overall rate of lever pressing decreased sharply for both rats. The decrease in overall rate was characterized by decreases in successive tenths of the fixed interval, with the sharpest decreases in absolute rate occurring during the second half of the intervals (Figure 3). The decrease in response rates during the last tenth of the fixed interval under FR 4: FOOD was associated with extended periods of no responding (Figures 3 and 4). The time base for calculation of rates during the last tenth of the fixed interval included any time that elapsed between the end of the interval and initiation of the terminal link. Thus, pauses longer than the duration of the fixed interval deflated the rate measures obtained for the last tenth of the interval. These pauses became as long as 1 hr in duration (Figure 4).

Otherwise, rates of lever pressing gradually increased throughout successive tenths of the initial link (Figures 3 and 4). Characteristic bivalued patterns of responding were maintained within individual FR 20: TOKEN components, especially under FR 1: FOOD and FR 2: FOOD. Under FR 4: FOOD, within-component patterning was occasionally disrupted (Figure 4).

Except for Rat T-23, as described earlier, the rats did not retrieve the marbles from the hopper until the terminal link was presented.

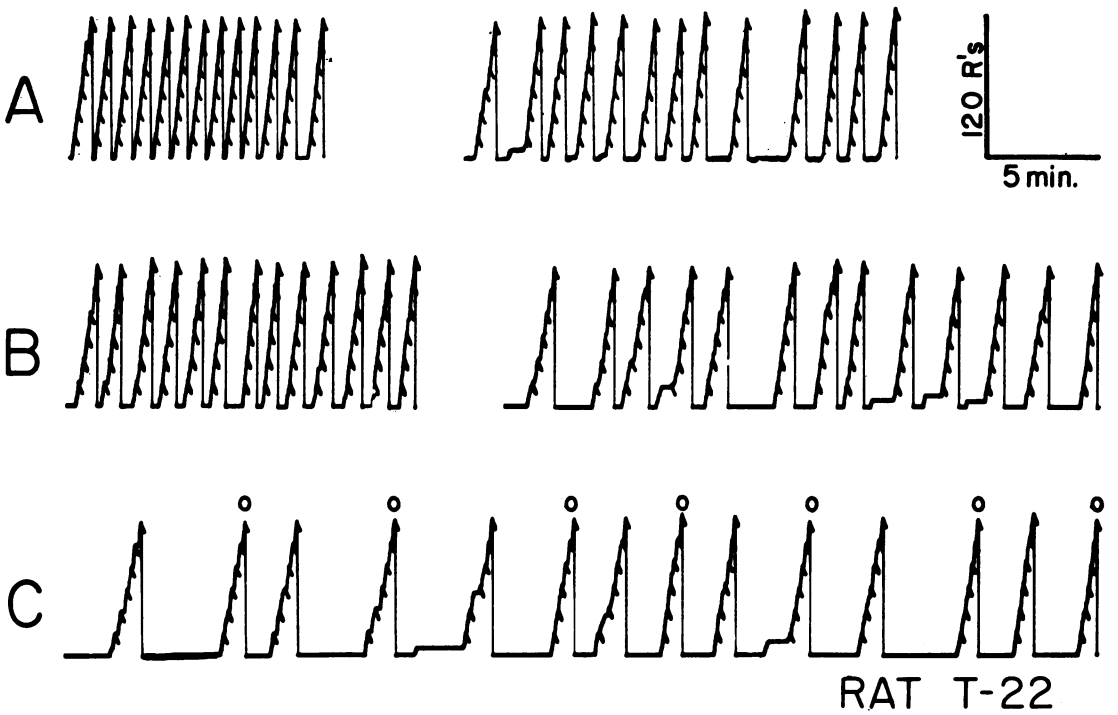

Fig. 2. Cumulative records of lever-pressing performance for Rat T-22. Diagonal hatchmarks indicate delivery of tokens on FR 20: TOKEN, and resets of the response pen indicate completions of the FR 6: EXCHANGE requirement. The recorder was inoperative during the terminal links. The schedule of food reinforcement was FR 1: FOOD and FR 6: FOOD, respectively, in the first and second records in both rows A and B, and FR 12: FOOD in the record in row C. The open circles above segments in row C indicate the initial links that were followed by a single food pellet during the terminal links.

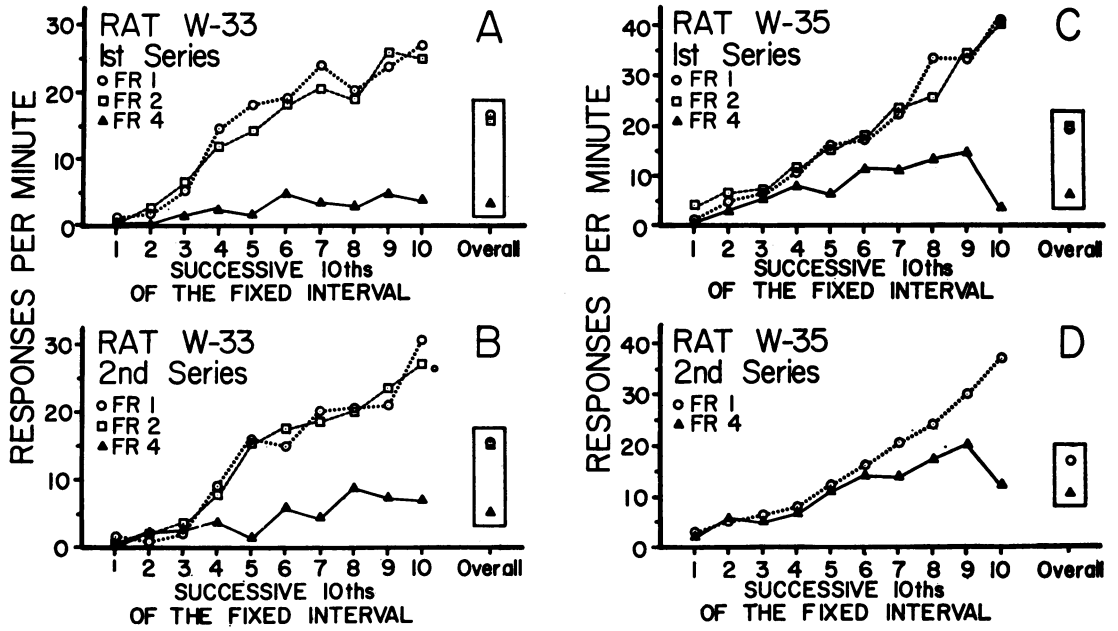

Fig. 3. Rates of lever pressing for Rats W-33 and W-35 at each value of the FR *n*: FOOD schedule. Shown are the mean response rates in each successive tenth of the FI: EXCHANGE schedule, and mean overall response rates.

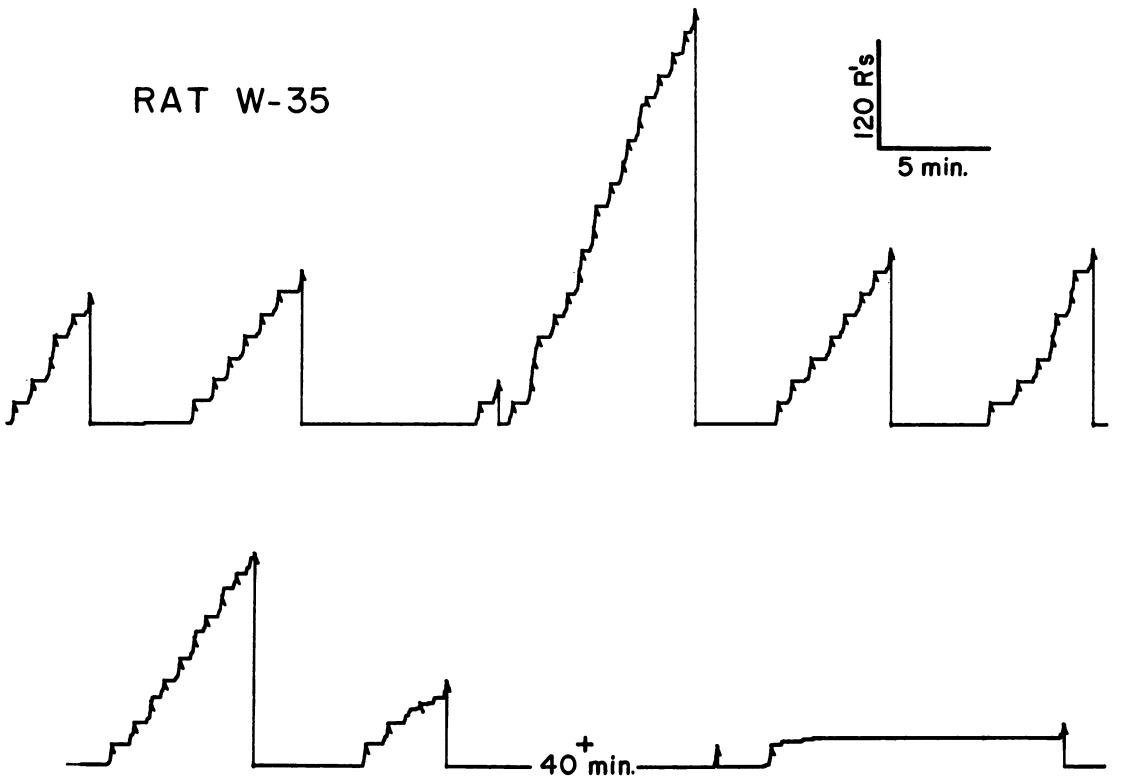

Fig. 4. Cumulative records of lever-pressing performance for Rat W-35. Diagonal hatchmarks indicate delivery of tokens on FR 20: TOKEN, and resets of the response pen indicate completions of the FI 9.0: EXCHANGE requirement. The recorder was inoperative during the terminal links. The top record shows a portion of a session under FR 1: FOOD, the bottom record shows a portion of a session under FR 4: FOOD. Note removal of a 40-min segment during which no responses were emitted.

DISCUSSION

Two aspects of the present results must be considered in relating them to those of previous experiments with chained schedules, second-order brief-stimulus schedules, and schedules of token reinforcement: (1) changes in rates and patterns of lever pressing during the initial link as a function of changes in the schedule of food presentation during the terminal link; and (2) patterns of responding controlled throughout sequences of FR *n:* TOKEN components under both FR 6: EXCHANGE and FI *t:* EXCHANGE schedules. The first consideration relates directly to analysis of the token-reinforcement paradigm as a form of chained schedule (Kelleher, 1966; Kelleher and Gollub, 1962). The second consideration also relates to this analysis and to the view that the token-reinforcement paradigm resembles a form of second-order brief-stimulus schedule (Marr, 1969; Waddell *et al.*, 1972).

With respect to the first consideration, the general effect of increasing the FR *n:* FOOD schedule during the terminal link was a decrease in overall rate of lever pressing during the initial link. These results are similar to those of experiments that have varied FR *n:* FOOD schedules in the terminal link of chained schedules containing either variable-interval (VI) schedules (Ferster and Skinner, 1957) or FI schedules (Ferster and Skinner, 1957; Hanson and Witoslawski, 1959) in the initial link. They are also comparable to experiments with chained schedules that have varied frequency of food presentation in the terminal link *via* either VI schedules (Findley, 1962) or FI schedules (Thomas, 1967). Related results have also been reported with concurrent chained schedules in experiments that have shown that probability of food presentation (Autor, 1969), frequency of food presentation (Autor, 1969; Herrnstein, 1964), and number of food presentations (Fantino and

Herrnstein, 1968) are all important determinants of responding in initial links. In the present experiment, the decreases in rates of lever pressing can be related only generally to several of these variables in interaction, since the probability of food presentation, frequency of food presentation, and number of food presentations covaried with the explicit manipulation of the FR *n:* FOOD schedule.

Most of the results with two-link chained schedules have been restricted to descriptions of changes in overall response rate during the initial link as a function of changes in frequency or probability of food presentation in the terminal link. Hanson and Witoslawski (1959) provided a more detailed description. Rats lever pressed on a two-link chained schedule containing an FI 4.0-min schedule in the initial link. The schedule in the terminal link was varied from FR 5: FOOD to FR 120: FOOD. Positively accelerated responding occurred in the initial link at FR 5: FOOD. As the schedule of food presentation in the terminal link was increased to FR 60: FOOD and then to FR 120: FOOD, the temporal distribution of responses in the initial link progressively flattened, with the sharpest decrease in absolute rates occurring in the last quarter of the fixed interval. Similar results were obtained in the present experiment with Rats W-33 and W-35, when FI *t* EXCHANGE schedules (combined with FR 20: TOKEN schedules) were in effect during the initial link. These results suggest that similar characteristics of responding are controlled within initial fixed-interval links of chained schedules independently of whether the unit of behavior is a single response, as in simple fixed-interval schedules, or a larger unit of behavior that itself contains fixed-ratio components, as in the present experiment.

Both the changes in overall response rates and the changes in fixed-interval patterning suggest that the initial-link–terminal-link sequence may be viewed as a form of chained schedule, supporting previous views to that effect (Kelleher, 1966; Kelleher and Gollub, 1962). As noted earlier, other characteristics of response patterning within the initial link also relate to this view and to the position that some features of the token-reinforcement arrangement resemble those of second-order brief-stimulus schedules (Marr, 1969; Waddell *et al.,* 1972). The characteristic bivalued pattern within individual FR *n:* TOKEN components are comparable to those ordinarily controlled by component FR schedules of brief exteroceptive stimulus changes in second-order schedules (Findley and Brady, 1965; Kelleher, 1966; Thomas and Stubbs, 1966). Terminating the FR *n:* TOKEN components by presenting the second link on FR 6: EXCHANGE controlled a bivalued pattern of completing the component schedules. These results are similar to those obtained by Thomas and Stubbs (1966), with a comparable second-order schedule in which each fifth consecutive FR 30: BRIEF STIMULUS component terminated with food presentation. Terminating the FR 20: TOKEN components by presenting the second link on FI *t:* EXCHANGE controlled a positively accelerated pattern of completing the component schedules. These results are similar to those obtained by Kelleher (1966) with a comparable second-order schedule in which food was presented following the first FR 20: BRIEF STIMULUS component completed after a 10.0-min fixed interval had elapsed. Similar results have also been obtained with comparable schedules of token reinforcement (Kelleher, 1957*b, c;* Waddell *et al.,* 1972).

Additional considerations also suggest that the sequencing of token deliveries within the initial link control patterns of responding in a manner more similar to second-order brief-stimulus schedules than to extended chained schedules. In the present experiment, with Rats T-22 and T-23, lever pressing was well maintained under FR 6: EXCHANGE, when six completions of the component FR *n;* TOKEN schedule were required for access to food. Similar results have been obtained in experiments with token reinforcement (Kelleher, 1956, 1957*b;* 1958; Malagodi, 1966, 1967*b*) and with comparable brief-stimulus schedules (Findley and Brady, 1965; Kelleher, 1966; Stubbs, 1971; Thomas and Stubbs, 1966), but have not been obtained with comparable extended chained schedules (Byrd, 1971; Findley, 1962; Kelleher, 1966; Kelleher and Gollub, 1962; Marr, 1969). The delivery of each token is a brief discrete event similar to the manner of presenting brief stimuli in second-order schedules. The gradual accumulation of tokens is a continuing stimulus change, similar to the manner of presenting discriminative stimuli in extended chained schedules. Apparently, the

brief-stimulus aspects of the total stimulus complex control patterning throughout sequences of components to a greater degree than do the discriminative-stimulus aspects. Comparable results have been obtained in experiments that have interpolated brief-stimulus presentations between successive discriminative stimuli in chained schedules (Byrd and Marr, 1969; Malagodi, DeWeese, and Johnston, 1973).

In conclusion, the present results suggest that the token-reinforcement paradigm may be viewed as comprising a form of two-link chained schedule, tokens being delivered in the initial link and food being presented in the terminal link. The first link may be viewed as itself comprising a form of second-order schedule more closely resembling brief-stimulus schedules than chained schedules. This view emphasizes the fact that three types of schedules are inherent to the paradigm, rather than the two ordinarily noted (the schedules of token reinforcement and the exchange schedules), and suggests a variety of schedule combinations that may be studied in any of the several forms of higher-order schedules. While such complex schedule arrangements may offer little in resolving traditional issues such as conditioned reinforcement (*cf.*, Stubbs, 1971; Stubbs and Cohen, 1972), they do provide procedures for constructing large samples of behavior and for identifying functional units (*cf.*, Findley, 1962).

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