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SCHEDULE-INDUCED LOCOMOTOR ACTIVITY IN HUMANS[1]

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In two experiments, humans received tokens either on a fixed-interval schedule for plunger pulling or various response-nondependent fixed-time schedules ranging from 16 to 140 seconds. Locomotor activity such as walking, shifting weight, or pacing was recorded in quarters of the interreinforcement interval to examine the induced characteristics of that behavior in humans. While performance was variable, several characteristics were present that have counterparts in experiments with nonhumans during periodic schedules of food reinforcement: (a) first quarter rates, and sometimes overall rates, of locomotor activity were greater during intervals that terminated in a visual stimulus and token delivery than those without; (b) overall rates of locomotor activity were greater during fixed-time 16-second schedules than during fixed-time 80- or 140-second schedules; (c) rates of locomotor activity decreased during the interreinforcement intervals; (d) locomotor activity was induced by response-dependent and response-nondependent token delivery. These results showed that the rate and temporal pattern of locomotor activity can be schedule-induced in humans.

Key words: fixed-interval schedule, fixed-time schedule, schedule-induced behavior, interim activities, locomotor activity, plunger pulling, humans

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Intermittent reinforcement not only increases the probability of the reinforced response, but also increases the probability of other classes of behavior that do not depend on response-reinforcer relationships to generate or maintain them. Such behaviors are commonly designated schedule-induced (Falk, 1971). When they predominate after reinforcement, they are referred to as interim activities (Staddon, 1977). Attack (Azrin, Hutchinson, and Hake, 1966), polydipsia (Falk, 1961), ambulation (Killeen, 1975; Anderson and Shettleworth, 1977), and response-produced timeout (Azrin, 1961) illustrate the variety of interim activities that are induced by schedules of reinforcement. Induced behaviors are as persistent as conditioned operants, but are not readily explained by current principles of learning (see Falk, 1971, 1977; Staddon, 1977 for reviews).

Induced behaviors have not been studied much with human subjects. Hitting inanimate objects (Fredriksen and Peterson, 1974; Kelly and Hake, 1970) and jaw clenching (Hutchinson, personal communication) have been reported, but few other induced activities have been identified. The limited number of experiments and the paucity of behaviors examined indicate that the phenomenon of schedule-induced behavior is in need of further study with humans.

The present study determined whether locomotor activity could be schedule-induced with humans. Specifically, four characteristics that have been reported in experiments with nonhumans were examined. First, the probability of induced behavior is greater during periods of intermittent reinforcement than during periods in which reinforcement is not available (Azrin *et al.*, 1966; Falk, 1966; Richards and Rilling, 1972). Second, the strength of many induced behaviors is greatest shortly after reinforcement and decreases with increases in postreinforcement time (Allen, Porter, and Arazie, 1975; Killeen, 1975; Richards and Rilling, 1972). Third, the rate of induced

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behaviors varies as a function of the interreinforcement interval (Brown and Flory, 1972; Cherek, Thompson, and Heistad, 1973; Falk, 1966), *e.g.*, attacking, drinking, and time spent in timeout increase, and then decrease, as the interreinforcement interval is lengthened. Finally, induced behaviors appear during both response-contingent and response-nondependent schedules (Cherek *et al.*, 1973; Flory, 1969; Staddon and Simmelhag, 1971).

In the present study, tokens could be earned by college students on a fixed-interval (FI) schedule, and by mentally retarded children during various response-nondependent fixed-time (FT) schedules. Unlike most schedule research with humans, the subjects remained standing and were free to move. Locomotor activity (walking, pacing, shifting weight, and jumping) was automatically recorded by sensors placed under the carpeting of the experimental space.

EXPERIMENT I

METHOD

Subjects

Two male and two female students enrolled in an introductory psychology course at a nearby university served as subjects.

Apparatus

The interior dimensions of the experimental room were 1.8 m long, 1.8 m wide, and 2.0 m high. The walls and ceiling were covered with sound-absorbent tile. A panel of aluminum construction, 62 cm square, was mounted in the center of one wall with its lower edge 69 cm above the floor. The response plunger (Gerbrands G6310), requiring a 3.0-N pull to operate, was located on the lower-left corner. Green, red, and orange lights, 1.3 cm in diameter, were located at the top of the panel. A coin dispenser (Gerbrands G5500), mounted behind the lower-right corner of the panel, dispensed poker chips into a rectangular receptacle covered by a clear Plexiglas window. The room was continuously lit and ventilated.

The floor of the room was covered by 144 rectangular switches (Packard Electronics, Warren, Ohio, #9673679). The switches were 8.0 cm long, 6.4 cm wide, and 0.05 cm high, and consisted of two parallel copper strips held apart by a layer of foam rubber. The top and bottom of the switches were coated with a thin layer of pliable plastic and required an average force of 8.9 N to close. Switch closure produced no audible sound. Four switches were wired in parallel in each square foot of the room. The output of each group of four switches was connected to a pulse former. When one switch was closed in a group, closure of another switch in that group did not produce an output. The sensors were covered by 1.0-cm thick carpeting.

Procedure

Inaccurate instructions and nonfunctional equipment were used to keep the subjects standing and unaware of the purpose of the study. The subjects first were told that they were to wear a "biometric transmitter". The experimenter then explained that the purpose of the study was physiological in nature. The "transmitter" had two EEG electrode leads, an operable test-circuit light, and a potentiometer.

Before each session, the neck area around the carotid arteries was cleaned with rubbing alcohol, and one electrode was placed over an artery on each side of the neck. Once the subject was in the experimental room, the test-circuit light was activated and the potentiometer was adjusted to make the transmitter appear to be operating. Before the first session, each subject was read the following instructions:

> While you are in this room, I would like you to wear this transmitter. Do not tamper with the sensors or the transmitting device. In addition, please remain in the standing position. Do not lean against the walls (experimenter demonstrates), sit down, or engage in physical exercises of any kind. You are free to move around the room if you wish. I will be back when the session is over.

The experimenter then answered any questions about the instructions and reread them. The subject was informed that the green light on the stimulus panel would light at the start of the session and go off when it ended.

Seven sessions, lasting 28 min, were conducted weekdays at approximately the same time each day. The first three sessions were baseline sessions during which 14, 2-min intervals elapsed without scheduled events, and the temporal distribution of locomotor activity was recorded in quarters of the intervals. In the remaining four sessions, a signalled FI 2-min schedule was studied. The delivery of poker chips, each worth 50 cents, served as reinforcements. The red panel light was lit 15 sec before reinforcement availability. This stimulus was included to reduce the possibility that the subjects would pull the plunger throughout the FI, thereby causing them to remain stationary. This signalled FI schedule also may be considered to be a multiple schedule (*i.e., mult* FI 15-sec EXT 105-sec schedule). Locomotor activity that occurred after the FI period had elapsed, but before the reinforced response did not accumulate in the last quarter of the interval. To eliminate locomotor activity related to acquiring or playing with poker chips during sessions, the chips were made inaccessible by locking the Plexiglas window of the token receptacle.

Before the first session with the signalled FI schedule, the subject was read the following instructions:

> During this part of the study, you may obtain 50 cents for each poker chip you earn. You can earn a poker chip by pulling this plunger (experimenter demonstrates) each time the red light comes on (experimenter points). Pulling the plunger when the red light is off has no effect on poker-chip delivery. When you have made a response, the orange light will flash (experimenter points). You may need to pull the bar more than once each time the light comes on. Remember not to lean against the walls or sit down during the session. As before, you are free to move around if you wish.

Again, the experimenter answered any questions about the instructions and reread them. Subjects were paid $2.00 per session as an incentive during the baseline sessions. Fixed-interval sessions were terminated after 14 chips were delivered (14, 2-min intervals). The door to the token receptacle was unlocked at the end of the session and the subject then gathered the chips and exchanged them for $7.00 once outside the experimental room.

Results

Figure 1 shows the rate of locomotor activity in quarters of 14, 2-min intervals for the second and third baseline sessions, and in quarters of the signalled FI 2-min schedule for subsequent sessions. The first session data were discarded because observations made from previous work indicated that movement was more frequent than in subsequent baseline sessions. Only Subject JS pulled the plunger during the baseline sessions (11 times). Generally, locomotor activity was distributed equally across quarters of the interval during the baseline sessions for Subjects JS and MG. The distributions were more variable for Subjects MD and FS, but there was no indication that locomotor activity dominated in any specific quarter of the baseline intervals. Because baseline intervals were equated to the programmed duration of the FI schedule, whatever differences did exist between baseline locomotor activity and subsequent locomotor activity on the FI schedule can be assessed.

During the FI schedule, subjects pulled the plunger only when the light was on. The mean plunger rates per second and the range for all sessions were: MD: 3.0 (2.6 to 3.4); JS: 1.3 (0.5 to 2.2); FS: 0.2 (0.1 to 0.3) and MG: 1.4 (1.1 to 1.5). With the exception of FS, subjects pulled the plunger at rapid, steady rates. Subject FS tended to pull the plunger toward the end of the light period. Tokens usually were delivered very close to their scheduled times so that the length of the FIs did not vary greatly from the length of the baseline intervals.

Figure 1 shows that for three of the four subjects (MD, FS, and JS) the maximum rate of locomotor activity occurred in the first quarter of the interval during the FI schedule. For these subjects, the rate during the first quarter of the interval during the four FI sessions was greater than the rate in any quarter of the interval during baseline sessions. The effect was most pronounced for Subject MD. The quarter with the minimum rate varied across subjects and sessions. The rate of locomotor activity decreased to the fourth quarter for Subject MD, the third to the fourth quarter for Subject FS, and the second to the fourth quarter for Subject JS. Finally, it should be noted that Subject MG's activity showed no systematic change during FI sessions.

Direct observation during FI sessions indicated that increased activity in the early part of the interval was not due to the subjects moving toward the locked dispenser to inspect the tokens as they were delivered. After four or five token deliveries, none of the subjects made noticeable movements toward the locked dispenser. The most conspicuous activity after token delivery was movement away, such as turning around, backing up, or pacing some distance away from it.

EXPERIMENT II

METHOD

Subjects

Two moderately retarded male adolescents, selected from the coeducational living quarters of the Northern Indiana State Hospital and Developmental. Disabilities Center, served. They were 12 and 13 yr old, had normal ambulatory capabilities, and exhibited receptive as well as expressive language skills. Both subjects were involved in a token economy in which pennies could be earned for completing certain tasks on the unit (*e.g.*, making beds, cleaning rooms, *etc.*). Pennies could be exchanged for edibles or access to desired activities. The plastic poker chips used as reinforcers in the experiment were substituted for pennies several days before the experiment began.

Apparatus

The apparatus was the same as that used in Experiment I, except that the plunger was removed.

Procedure

A total of 36 sessions was conducted five days a week at approximately the same time each day. Before the start of each session, the subject was allowed to choose an item from a variety of foods (*e.g.*, candies, box of cereal, crackers, *etc.*). The item selected was set aside and could be purchased with poker chips at the end of the session. One experimenter remained in the experimental room with the subject throughout each session. The experimenter stood in the right-rear corner of the room, and the sensors underneath the experimenter's standing position (one square foot) were disconnected. The experimenter's function was to prompt the subjects verbally not to lean against the walls, deliver social praise simultaneously with token delivery, and terminate the session if necessary. No explicit instructions were given to the subjects other than to indicate that tokens could be earned by staying inside the experimental room.

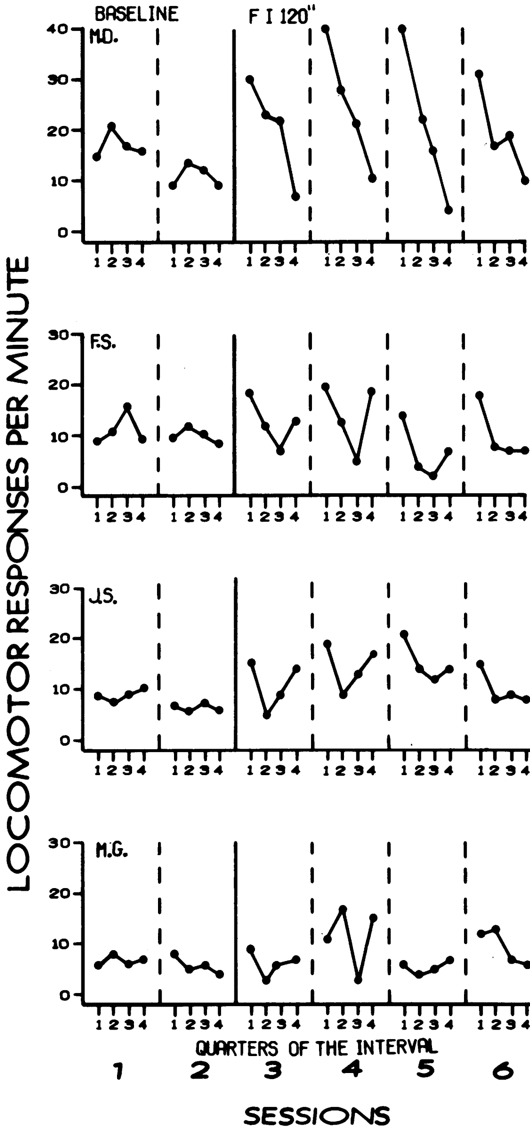

Fig. 1. Locomotor activity responses per minute in quarters of the interval during baseline and fixed-interval sessions.

For the first 26 sessions, pairs of baseline sessions alternated with pairs of sessions in which a signalled FT schedule was in effect. During baseline sessions, intervals elapsed without a visual stimulus and token delivery. The duration of the baseline intervals was equated to the duration of the signalled FT schedules, so that rate of locomotor activity between quarters of baseline and FT intervals could be compared.

Three signalled FT schedules were studied in the order: FT 40-sec, FT 80-sec, and FT 16-sec (see Figure 2). During FT and baseline sessions, the temporal distribution of locomotor activity was recorded in quarters of the interval. The red light on the stimulus panel was lit in the last eighth of the three FT schedules (*i.e.*, 5 sec, 10 sec, and 2 sec respectively), and was followed by delivery of a token. The green panel light was lit for the duration of the session. During baseline sessions, 18 poker chips were placed in the token receptacle. For all sessions, the door to the token receptacle was locked before the subject entered the experimental room. At the end of each session, the door was unlocked and the subject collected the tokens which then were exchanged for the item selected at the beginning of the session.

For the remaining 10 sessions, the FT duration was varied every two sessions in the sequence: FT 16-, FT 80-, FT 16-, FT 140-, and FT 16-sec. When FT 140-sec was scheduled, sessions were terminated after 14 reinforcers to avoid excessive session length. Other procedural details were the same as in the previous condition.

Results

Data were analyzed in blocks of two sessions. Rates derived from these two-session averages generally were representative of individual sessions.

Figure 2 presents the temporal distribution of locomotor activity during the 26 sessions when blocks of two baseline and two FT sessions were alternated. Considering first the overall session rate of locomotor activity (dashed line), in almost every case the rate increased from the previous baseline rate during each block of FT sessions, and then decreased when sessions of baseline were reinstated. There was no clear relationship between the overall session rate of locomotor activity and the length of the interreinforcement interval.

The more detailed analysis in terms of quarters of the intervals shows that during the FT schedules, the maximum rate of locomotor activity occurred in the first quarter of the interval, and typically decreased across successive quarters. This distribution of locomotor activity was rarely present during baseline sessions.

Figure 3 shows the subsequent 10 sessions when the FT schedule was changed every two sessions. The overall rate of locomotor activity was higher under the FT 16-sec schedule than under either the FT 80-sec or the FT 140-sec schedule. Inspection of the temporal distribution of activity indicates that this difference in overall rate generally was due to higher rates in the first, and, in some cases, the second quarter of the FT 16-sec schedules.

Throughout the experiment, postreinforcement activities that were distinguishable from other interval behaviors included moving away from the stimulus panel, vocalizing, and clapping hands. Subject KS often rocked with one foot in front of the other throughout the interreinforcement interval. During the shortest interval, FT 16-sec, the subjects stayed noticeably closer to the stimulus panel than during the other schedules. The subjects were also observed to approach the panel when the red light came on before token delivery.

DISCUSSION

The present study demonstrated that the locomotor activity of humans can be schedule-induced. By comparison with baseline rates, the rate of locomotor activity increased in the first quarter of the intervals of both the FI and FT schedules, as well as during the overall session with the FT schedules. Similar procedures have been used to examine schedule-induced increases in attack by pigeons (Richards and Rilling, 1972), and in action patterns such as walking by hamsters (Anderson and Shettleworth, 1977).

In addition to showing that locomotor activity in humans can be schedule-induced, the results indicated that this behavior assumed the role of an interim activity. Under periodic schedules, the rate (Killeen, 1975, Experiment 1b) and the probability (Anderson and Shettleworth, 1977) of ambulatory activity has been found to peak shortly after reinforcement and then decrease with increases in postreinforcement time. The present study observed similar temporal organizations of behavior. The increase in locomotor activity associated with the schedules cannot be explained by adventitious reinforcement, because locomotor activity predominated in the quarter of the interval that

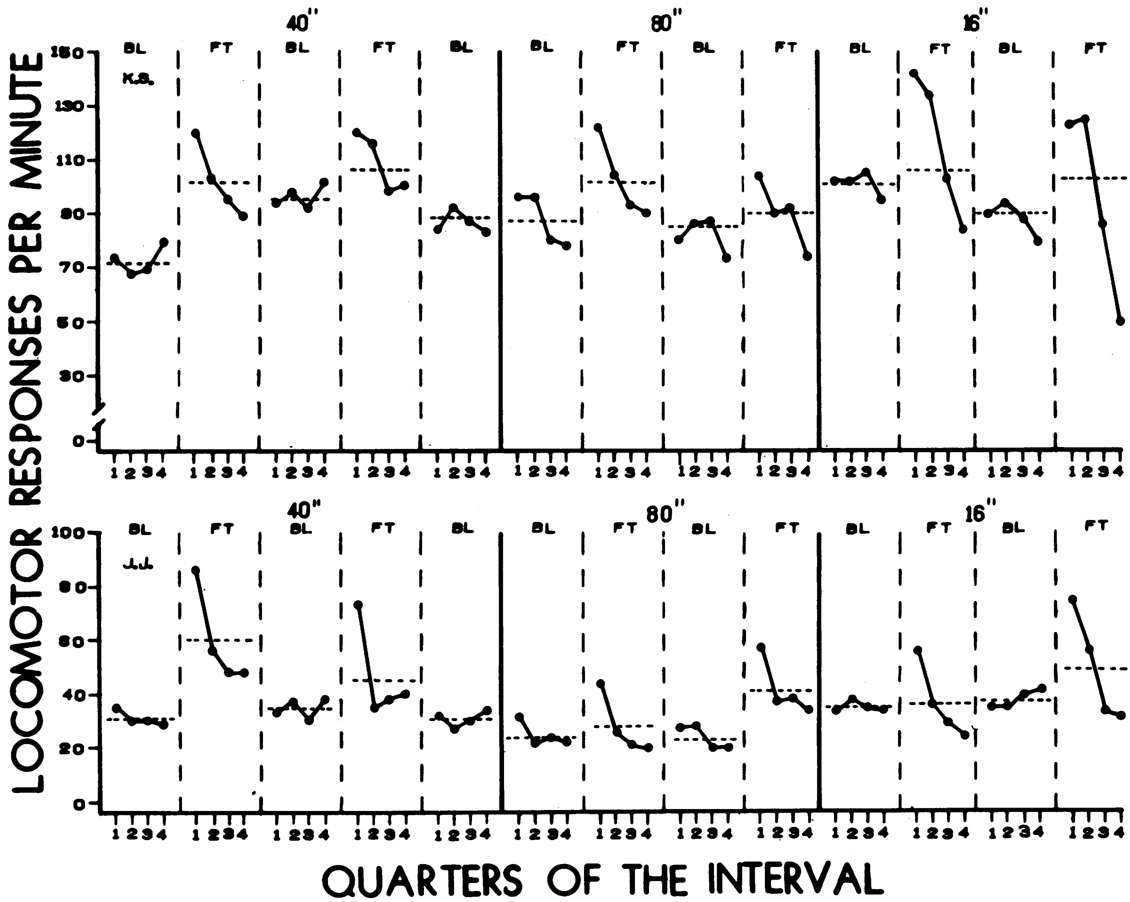

Fig. 2. Mean locomotor activity responses per minute in quarters of the interval in blocks of two baseline (BL) and fixed-time (FT) sessions. The dashed horizontal line indicates the mean overall rate. The durations of the FT schedules are at the top of the panels.

was furthest removed from token delivery. Further, distributions of locomotor activity were not simply due to a decay of activity initiated by token delivery. If this were the case, the amount initiated per token would be exhausted in different portions of schedules that varied in length. However, in Experiment II the rate of locomotor activity typically decreased from the first to the fourth quarter of FT schedules ranging from 16 to 140 sec. These results emphasize the role of the interreinforcement interval in organizing the temporal distribution of locomotor activity.

One factor that may have influenced the temporal distribution of locomotor activity was the signal in the last eighth of the interreinforcement interval. During the signal period of the FT schedules, the subjects were noticeably more quiescent. They would orientate toward or approach the stimulus panel and appear to wait for token delivery. Killeen (1975, Experiment 3c) also found that a visual stimulus (flashing houselight) paired with food presentation inhibited locomotor activity at the end of an FT-60-sec schedule, and it is possible that such a stimulus-reinforcer relationship inhibited locomotor activity in the present experiment.

In some experiments with nonhumans, a bitonic function (inverted U), has been reported between the length of the interreinforcement interval and the amount of schedule-induced behavior. By comparison, when blocks of short and long FT schedules alternated every two sessions, the overall rate of locomotor activity was greatest under FT 16-sec than under FT 80- or FT 140-sec. These results are more analogous to Killeen's finding (1975, Experiment 1a) that the overall rate of locomotor activity decreased monotonically with

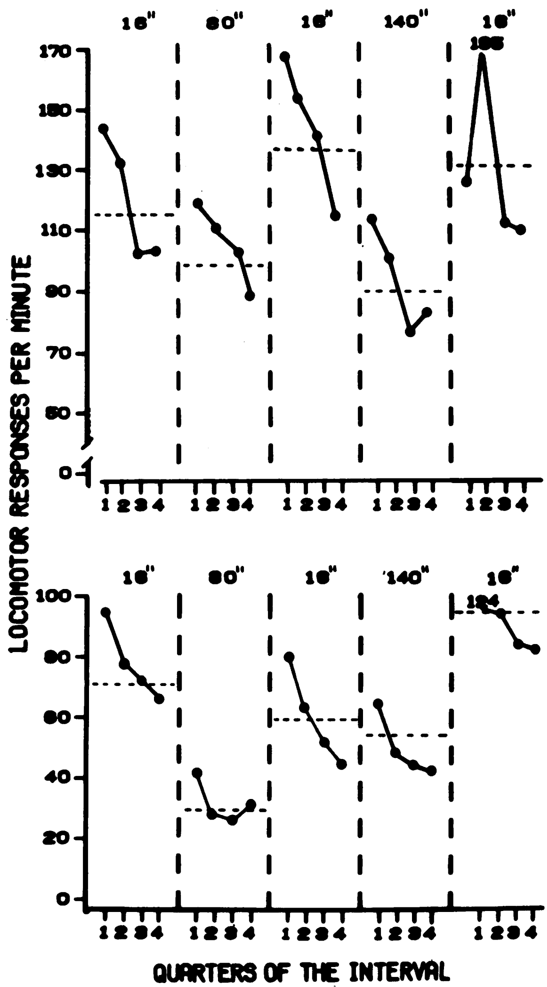

Fig. 3. Mean locomotor activity responses per minute in quarters of the interval in blocks of two sessions. The dashed horizontal line indicates the mean overall rate. The durations of the FT schedules are at the top of the panels.

increases in the interreinforcement-interval duration of FT schedules. However, the present study examined a relatively small range of schedule values; had a wider range been examined and stability achieved under each schedule, perhaps a more definite relationship between the length of the interreinforcement interval and the rate of locomotor activity would emerge. The lack of a relationship between the length of the interreinforcement interval and locomotor activity when baseline sessions were interspersed between FT sessions (see Figure 2) may have been due to the experimental design and to variability in the type of activity that activated the floor sensors. After token delivery, Subject JJ jumped up and down and turned in circles, which activated the floor sensors at an unusually high rate. This activity was seen only in the first block of FT 40-sec sessions. Alternating sessions of baseline and FT may have also obscured schedule effects.

In conclusion, several characteristics of schedule-induced behavior were demonstrated during periodic schedules of token delivery with humans. The effects of FI and FT token delivery on locomotor activity and its temporal organization were found to be comparable to the effects of these schedules with food reinforcement with nonhuman subjects.

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