

Schedule-Induced Cigarette Self-Administration

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Received 5 February 1982

CHEREK, D. R. *Schedule-induced cigarette self-administration*. PHARMAC. BIOCHEM. BEHAV. 17(3) 523-527, 1982.—Cigarette self-administration was studied in a controlled laboratory setting by automated recording of the various components of smoking behavior. The effects of intermittent scheduled monetary reinforcement presentation on cigarette smoking was determined in an attempt to demonstrate schedule-induced cigarette self-administration. Schedule-induced cigarette self-administration was indicated by changes in some of the topographical components of cigarette smoking behavior, e.g., puff frequency and mean puffs per cigarette, as a function of changes in the fixed interval value of a monetary reinforcement schedule. While the number of cigarettes smoked changed only slightly following changes in the FI value of the monetary reinforcement schedule, other components of cigarette smoking behavior, particularly puff frequency and mean puffs per cigarette, were significantly altered. Cigarette puffs were most likely to occur immediately following monetary reinforcement presentation or in the initial segment of the next fixed interval. The demonstration of schedule-induced self-administration in human adds another common factor found to influence infrahuman and human drug self-administration.

Cigarette smoking Drug self-administration Schedule-induced behavior

AN experimental analysis of drug dependence considers drugs to be reinforcers which maintain behavior leading to their self-administration. The pharmacological properties of the drug and the scheduling of its presentation are fundamental determinants of the drug's ability to maintain self-administration behavior. However, drug self-administration cannot be considered apart from the historical and current environmental situation in which it occurs. Whether or not a particular drug will be effective in initiating and maintaining self-administration behavior also depends upon the environmental context in which the drug is made available. The intermittent schedule presentation of another reinforcer, e.g., food, is one environmental situation which has been found to initiate and maintain infrahuman drug self-administration.

Drug self-administration in such situations is referred to as schedule-induced drug self-administration, and is one of several schedule-induced behaviors which include polydipsia, aggression and escape [8]. Schedule-induced behavior is behavior occurring at increased probability during the intermittent scheduled presentation of another reinforcer. Such schedule-induced activities are facilitated by the schedule when compared to pre- and post-schedule baselines when no reinforcer is presented (see review, [25]). Early investigations of schedule-induced behavior have shown that intermittent schedule of food presentation were able to induce excessive drinking of water in laboratory animals that were not water deprived [7,24]. Later it was reported that laboratory animals would consume large volumes of ethanol

solutions when food was presented on an intermittent schedule [9, 13, 20]. Control laboratory animals provided with free access to ethanol solutions but not exposed to intermittent schedules of food presentation consumed very little ethanol. The intermittent scheduled presentation of food was able to induce ethanol self-administration and establish it as a reinforcer. In addition, the intermittent scheduling of food presentation has also been found to induce self-administration of amphetamine [26], barbiturates [15,19], and opiates [16, 17, 23]. These studies of infrahuman drug self-administration induced by the intermittent presentation of food have demonstrated the importance of environmental events in determining the ability of certain drugs to serve as reinforcers.

The relationships established in the experimental analysis of infrahuman drug self-administration have been applied to studies of human drug self-administration [1, 2, 21, 22, 27]. These studies have "involved establishing drug self-administration behavior under controlled experimental conditions, providing the basis for examining the effects of specific environmental manipulations" [10]. In the present study, we have investigated cigarette self-administration in a controlled laboratory setting. Within this context, cigarette smoking is regarded as drug self-administration maintained by the reinforcing properties associated with its use. More specifically, we were interested in studying the effects of intermittent scheduled monetary reinforcement presentation on cigarette smoking.

METHOD

Subjects

Two male (S-30 and S-38) and one female (S-31) volunteers participated in the experiment after giving their informed consent. These subjects were recruited through advertisements soliciting participation in a research project involving psychomotor performance, monetary payment and cigarette smoking. All subjects were currently smoking at least fifteen cigarettes per day and had been smoking for at least four years. At the end of the experiment, subjects were provided with information on smoking cessation techniques and encouraged to stop smoking.

Cigarette Smoking Behavior

Cigarette smoking was monitored by having subjects smoke each cigarette through a plastic cigarette holder which was connected to a pressure sensitive switch (Micro Pneumatic Logic, MPL-502-V) by 19 gauge needles and 18 gauge acid resistant flexible rubber tubing [12]. An Aquafilter, with all filtering material removed, was used as a cigarette holder. This holder did not filter the smoke in any way, and subjects reported that they could detect no differences in the inhalation, taste, etc. of cigarettes using the device. The air pressure switch (which responds to ≥ 5 mmHg pressure drop) was mounted on the response console and connected to control logic equipment (Coulbourn Instruments) which allowed the recording of the occurrence of each cigarette puff and its duration. The following components of cigarette self-administration were measured: (1) number of cigarettes smoked, (2) puff frequency, and (3) puff duration. At the beginning of each session, subjects were provided with a pack of their preferred brand of cigarettes. The subjects were able to initiate cigarette smoking at any time during the experimental sessions.

Procedure

Research subjects came into the Medical Center for two hour experimental sessions five days per week. Prior to each daily session, subjects remained in a waiting area for 30 minutes and were not allowed to smoke. This served to standardize the amount of cigarette deprivation prior to the beginning of the experimental session. At the end of the waiting period, the subjects were taken into an experimental room and seated in front of a response console (Testan HT300/2). They remained in this room for the next two hours. Cold water was available by operating a commercial vacuum thermos. A light on the front of the console was illuminated at the beginning of the two hour session and was extinguished at the end of the session.

The subjects were told that pushing a button mounted on the console would result in the accumulation of money. They were given no information about the schedule of monetary reinforcement and were simply told that not every button press would result in monetary reinforcement presentation. Subjects were also instructed that cigarette smoking would not influence the amount of money earned in daily sessions. Pushing the button was initially maintained by a response-initiated fixed-interval (FI) 60 second schedule [18]. On such a schedule, the first response after reinforcement presentation initiated the next 60 second interval, and the first response after the interval elapsed resulted in the next reinforcement presentation. This schedule was employed, since

TABLE I

MEAN VALUES (N=4) OF DIFFERENT COMPONENTS OF CIGARETTE SMOKING BEHAVIOR AS A FUNCTION OF THE FIXED INTERVAL OF THE MONETARY REINFORCEMENT SCHEDULE

Subject Number:	S-30	S-31	S-38
FI Value (sec)			
	Mean Number of Cigarettes Smoked \pm SEM		
30	6.0 \pm 0.0	4.5 \pm 0.3	4.0 \pm 0.0
60	5.0 \pm 0.0	3.8 \pm 0.5	3.0 \pm 0.0
120	6.5 \pm 0.3	5.0 \pm 0.0	4.0 \pm 0.4
240	6.3 \pm 0.4	5.0 \pm 0.0	4.0 \pm 0.0
	Mean Puffs Per Cigarette \pm SEM		
30	16.6 \pm 0.4	13.7 \pm 0.4	12.9 \pm 0.7
60	24.2 \pm 0.5	14.5 \pm 1.4	16.2 \pm 0.6
120	21.8 \pm 1.3	15.3 \pm 1.0	18.3 \pm 1.8
240	16.0 \pm 1.3	13.3 \pm 0.4	15.9 \pm 0.3
	Mean Puffs Per Hour \pm SEM		
30	49.8 \pm 1.2	29.1 \pm 1.4	25.4 \pm 1.5
60	60.4 \pm 1.3	26.3 \pm 0.7	24.1 \pm 0.8
120	70.4 \pm 1.5	38.3 \pm 1.3	35.6 \pm 1.5
240	49.1 \pm 0.6	33.1 \pm 0.9	31.9 \pm 0.7
	Mean Puff Duration (Sec) \pm SEM		
30	0.64 \pm 0.03	0.91 \pm 0.03	0.51 \pm 0.00
60	0.75 \pm 0.07	0.82 \pm 0.06	0.49 \pm 0.02
120	0.70 \pm 0.03	0.79 \pm 0.03	0.55 \pm 0.02
240	0.70 \pm 0.03	0.71 \pm 0.03	0.62 \pm 0.02

All values represent the means \pm SEM of the last four sessions at each FI value.

fixed interval schedules have been found to induce infrahuman (e.g., [5]) and human behavior [14]. Each reinforcement presentation was indicated to the subject by the incrementing of a counter (Testan HT464) mounted on the console adjacent to the pushbutton. Each point on the counter was equal to ten cents. Thus, a count of 003 was equivalent to thirty cents, and a count of 030 equivalent to three dollars, etc. For two hours, the subjects were given access to the pushbutton. The money earned during the session was paid to the subjects daily (ranged from \$2.70 to \$22.00).

Each research subject was exposed to the following sequence of FI monetary reinforcement schedule values over successive sessions: 60, 120, 240 and 30 seconds. The maximum monetary reinforcement condition, i.e., FI 30 seconds, was introduced last to reduce the probability that subjects would discontinue their participation before the study was completed. The FI value for each experimental session remained unchanged until the rate of puffing, i.e., puffs per hour, varied less than ± 10 percent for four successive sessions. The rate of puffing was selected as the criterion for introducing changes in FI value, since other studies [4,11] have indicated that this component of smoking behavior is the most sensitive to experimental manipulations.

RESULTS

The various components of cigarette smoking behavior were compared at the four FI values (30, 60, 120 and 240

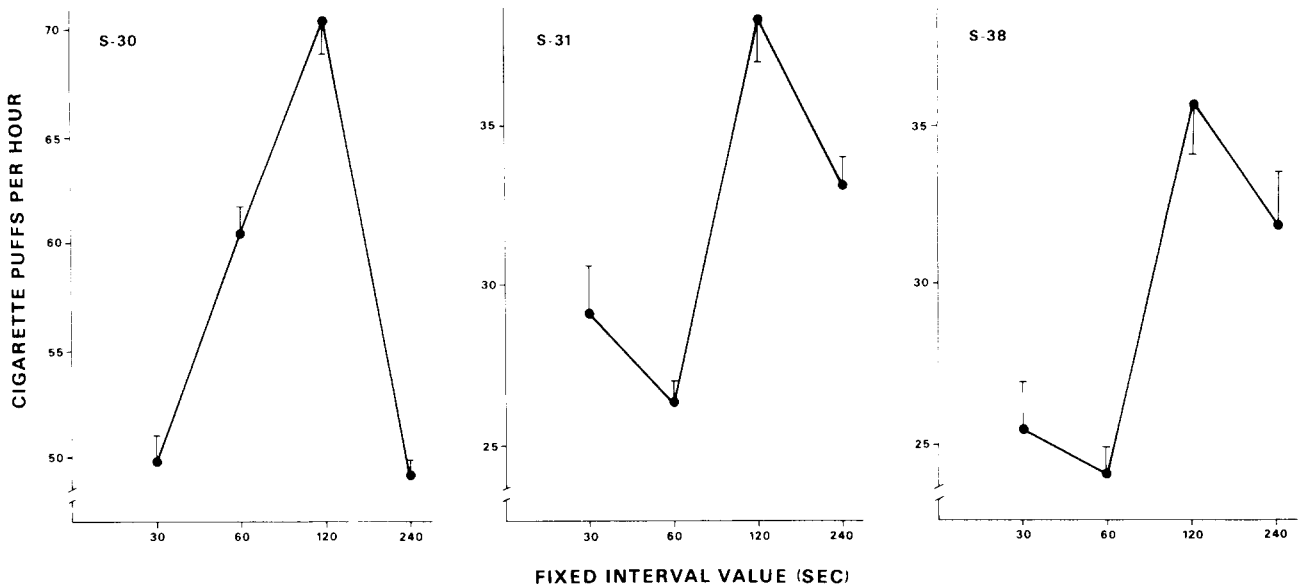


FIG. 1. The rate of cigarette smoking, i.e., puffs per hour, for all three subjects at each FI value of the monetary reinforcement is shown in Fig. 1. The data points represent the mean puff rate for the last four sessions at each FI value. The vertical lines at each data point are \pm SEM.

seconds) of monetary reinforcement. Smoking behavior data for subjects S-30, S-31 and S-38 appears in Table 1. The values reported represent the mean (\pm SEM) for the last four sessions at each FI value. For all subjects, the changes in the number of cigarettes smoked were slight, with more cigarettes being smoked at FI values of 120 and 240 seconds. Marked changes in the rate of puffing were seen as a function of changes in the FI value of the monetary reinforcement schedule. The rate of puffing, i.e., puffs per hour at each FI value is also shown in Fig. 1. All three subjects had the highest rates of puffing at an FI value of 120 seconds; the puffing rate was lower at FI values lower and higher than 120 seconds. The subjects did differ in the rate of puffing that occurred during FI values other than 120 seconds, although the relationship between puff rate and FI value is very similar for subjects S-31 and S-38. For subject S-30, the second highest puff rate was seen at an FI value of 60 seconds and the lowest puff rate occurred at an FI 240 seconds. The second highest puff rates for subjects S-31 and S-38 were at an FI value of 240 seconds and the lowest puff rates were at an FI 60 seconds. The number of puffs per cigarette was highest at FI values of 60 and 120 seconds and lower at FI values of 30 and 240 seconds (refer to Table 1). The mean duration of each puff remained unchanged at the different FI values for all subjects.

The rate of button pressing during the last four sessions at each FI value is shown in Table 2. Subjects S-30 and S-38 maintained high rates of button pressing (100 to 200 resp/min) at all FI values. Subject S-31 maintained a low to moderate rate of button pressing which increased at each successive FI value. There were no consistent relationships between puffing rates and button pressing rates across the three subjects. The puffing rate of Subject S-38 increased as button pressing rate decreased at the different FI values. The other two subjects did not show any systematic relationship between puffing and button pressing rates.

TABLE 2
RATE OF MONETARY REINFORCED RESPONDING (RESP/MIN)

FI Value (sec)	S-30	S-31	S-38
30	176 \pm 6	68 \pm 15	142 \pm 26
60	151 \pm 29	9 \pm 1	205 \pm 30
120	212 \pm 8	28 \pm 2	117 \pm 17
240	191 \pm 2	38 \pm 2	120 \pm 6

Mean rates of button pressing as a function of the fixed interval value of the monetary reinforcement schedule.

All values represent the means \pm SEM of the last four sessions at each FI value.

The number of cigarette puffs during successive segments of the fixed interval on the last four sessions at each FI value is shown in Table 3. Each FI was divided into three equal segments of 10, 20, 30 or 80 seconds. For all three subjects, approximately 70 percent of the cigarette puffs occurred during the first segment of the fixed interval. This first segment represents the time between monetary reinforcement, i.e., point delivery and the first 10 to 80 seconds of the next fixed interval. Since the subjects initiated the next interval immediately following reinforcement presentation, the duration of the first segment was equal to the second and third segments. Fifteen to 25 percent of the cigarette puffs occurred during the second segment of the fixed interval which represents the middle of the fixed interval. The lowest number of cigarette puffs from 5 to 15 percent occurred during the third segment of the fixed interval from the last segment up to monetary reinforcement delivery.

DISCUSSION

This study has demonstrated schedule-induced cigarette self-administration in humans. One of the most powerful demonstrations of schedule-induced behavior is observing changes in the rate of behavior, e.g., cigarette self-administration, as a function of changes in the FI value of the inducing schedule. The results of this experiment show that changes in the FI value of a monetary reinforcement schedule resulted in significant changes in the rate of cigarette smoking. Changes in puff duration and number of cigarettes smoked at the different FI values were minimal. The effect of FI value on cigarette puffing rate adds support to a previous preliminary report of schedule-induced cigarette smoking [4].

The most consistent finding of the present study was the temporal locus of cigarette puffs in relation to the FI schedule of monetary reinforcement. More than two-thirds of the cigarette puffs occurred immediately after monetary reinforcement presentation or during the initial portion of the next fixed interval. The majority of cigarette puffs continued to occur in the post-reinforcement segment of the schedule as the FI value was changed. This indicates that the intermittent presentation of points was exerting some control over the temporal pattern of cigarette puffs. The observation that most cigarette puffs occurred during the post-reinforcement segment of the FI schedule is consistent with the locus of other schedule-induced behaviors, such as aggression and polydipsia (e.g., [5, 8, 25]).

Schedule-induced cigarette smoking in the present study adds drug self-administration to the types of schedule-induced behaviors evidenced in humans. Schedule-induced water drinking has been demonstrated in hospitalized patients during responding maintained by FI monetary reinforcement [14]. Schedule-induced increases in observed motor activity were reported during playing games of chance [6,30] and responding for candy [28] on an FI schedule. Another investigation of schedule-induced motor activity during FI scheduled access to a cognitive maze drawing task, also reported increases in cigarette smoking during maze access [29]. These and the present study clearly demonstrate the across species validity of schedule-induced behavior and indicate that human schedule-induced behavior can be studied in a controlled laboratory environment.

The demonstration of schedule-induced cigarette smoking emphasizes the control which environmental stimuli can exert over cigarette smoking behavior. The intermittent presentation of points was found to set the occasion for and

TABLE 3
NUMBER OF CIGARETTE PUFFS

FI Value (sec)	Total	Fixed Interval Segments		
		1st	2nd	3rd
Subject S-30				
30	398	322	51	25
60	481	364	83	34
120	563	426	88	49
240	393	237	97	59
Subject S-31				
30	233	169	53	11
60	210	146	37	27
120	306	205	63	38
240	265	173	63	29
Subject S-38				
30	203	128	49	26
60	194	155	25	14
120	285	203	59	23
240	255	157	62	36

Number of cigarette puffs during three successive segments of the fixed interval at each FI value.

Values represent the total number of puffs in each segment during the last four sessions at each FI value.

influence the pattern of cigarette puffing. As with other schedule-induced behaviors, cigarette puffs were found to occur primarily in the post-reinforcement segment of the FI monetary reinforcement schedule. Several investigators have suggested that the aversive properties associated with the post-reinforcement period, i.e., low probability of reinforcer presentation, are the setting and/or eliciting conditions which result in schedule-induced behavior [5, 8, 25]. These aversive properties might also augment the pharmacological reinforcing properties of tobacco smoking. In support of this premise, smoking has recently been found to produce selective dose-dependent (in terms of nicotine) decreases in human aggressive behavior elicited by presentation of aversive stimuli [3]. Reducing the eliciting properties of aversive environmental stimuli would be a potentially powerful reinforcing consequence of tobacco smoking.

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