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Concurrent drinking by pigeons on fixed-interval reinforcement schedules

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Three experienced pigeons were exposed to at least ten consecutive 100-min sessions on each of three food-reinforced fixed-interval (FI) schedules: FI 50-sec, FI 100-sec and FI 200-sec. Water was freely available. Drinking was largely confined to the first third of each fixed interval, and the mean sessional water intake was directly related to the food-reinforcement rate for each animal. The animals drank very quickly, i.e., 3-4 ml/sec, but the drinking bouts were brief, i.e., 0.8-1.4 sec, and infrequent, i.e., 2-5/hr. The parameters describing concurrent drinking in the pigeon are strikingly different from those describing rats' drinking under similar reinforcement schedules, which may contribute to the difficulty in demonstrating schedule-induced polydipsia in the pigeon.

Rats receiving food under fixed-interval (FI), and many other, reinforcement schedules drink large quantities of concurrently available water [6]. This phenomenon is referred to as scheduled-induced polydipsia because the concurrent drinking which occurs under certain reinforcement schedules is excessive relative to that which occurs under some reference or control condition [6,12,22].

Schedule-induced polydipsia has been obtained in the large majority of the mammalian species tested. It has been demonstrated in several strains of rats [6] and mice [16,23], in rhesus monkeys [1,19], squirrel monkeys [3], Java macaques [2] and man [11]. Failures to obtain schedule-induced polydipsia have been reported for hamsters [26], gerbils [4,26] and one mouse strain [23], while the results with guinea pigs have been mixed [14,18,24].

The pigeon is the only non-mammalian species for which concurrent drinking has been examined [8,15,22,25,27] and, with one exception [22], schedule-induced polydipsia has not been obtained. The present study was conducted in order to describe the characteristics of concurrent drinking in pigeons exposed to FI reinforcement schedules, and to compare them with those of rats exhibiting schedule-induced polydipsia under similar reinforcement schedules. Differences in the drinking characteristics of those species which exhibit schedule-induced polydipsia and those species which do not might help to identify the factors responsible for this phenomenon.

Method

Animals

Three one-and-a-half-year-old male White Carneaux pigeons were maintained at 80% of their respective free-feeding body weights throughout the experiment. Each had received approximately 50 one-hr test sessions on a food-reinforced FI 100-sec schedule, with water concurrently available. The animals were individually housed under constant illumination in a room maintained at between 20°C and 25°C.

Apparatus

Experimental sessions were conducted in a Grason-Stadler animal chamber (Model E3125AA-3) with a Grason-Stadler three-key pigeon station (Model E-6446C). The two side keys on the pigeon station were covered with black electrical tape. Grain was presented from a magazine directly below the center key. Water was continuously available in a 170 ml glass located in the left front corner of the chamber. The glass was held in the centerpiece of an H-shaped wooden holder. The holder had a roof which prevented the animals from perching on the water-glass or the holder, without limiting their access to the water.

A photocell and light source were set diagonally apart in the center-piece of the water holder, at a level 1 cm below the top of the water glass. Before each session the water glass was filled with water to a level 1 cm below the light beam. During a session, interruptions of the light beam were recorded as drinks. Occasional observation of the animals indicated that the animals always interrupted the light beams with their heads while drinking. The animal chamber was illuminated throughout every session by the light source used in the recording of drinking, and by a white response key during test sessions involving FI food-reinforcement schedules. The experimental room was dark and was maintained at a temperature of 20-22°C. Standard relay programming and recording equipment was located in an adjoining room.

Procedure

Pretraining was unnecessary because of the experimental history of the animals. Each animal was exposed to the following treatments in the order shown: the number of sessions under each condition for animals S1, S2 and S3, respectively, are shown in brackets: Control sessions (7, 7, 7), FI 100-sec schedule (10, 10, 10), control sessions (11, 11, 11), FI 200-sec schedule (13, 10, 10), control sessions (10, 10, 10), FI 50-sec schedule (11, 12, 12), control sessions (5, 5, 5). The data from ten experimental sessions and four control sessions were lost because of recording apparatus failure or experimenter error.

During the experimental sessions animals were required to peck the white response key at the end of the programmed fixed interval to obtain 3.0 sec access to mixed grain. The white keylight was extinguished during grain presentations. Experimental sessions lasted about 100 min, with the animal remaining in the test chamber for a mean of about 20 min following each experimental session. The animals received 30, 60 and 120 food presentations on the FI 200-sec, FI 100-sec and FI 50-sec schedules, respectively. Control sessions were two hours long, to equal

the total time spent in the operant chamber during experimental sessions. The response key was unlighted and inoperative during control sessions, and 15g of mixed grain were available in the food magazine at the start of each session (chosen to match the amount of food consumed under the FI 50-sec schedule).

For the first seven control sessions, the only drinking measure taken was the total water intake/ session (ml). For subsequent sessions the total number of drinks (photocell beam interruptions), drinking time (sec) and number of bouts were also recorded. On experimental sessions, all of the drinks which occurred during a single interval comprised a bout. Thus, the bout frequency indicated the total number of intervals in a session on which an animal drank. The bout frequency for control sessions was determined as follows: For the five control sessions preceding and following a given experimental condition, drinks which were separated by less than the interpolated FI duration were counted as being in the same bout. When consecutive drinks were separated by more than the interpolated FI duration they were considered to be in separate bouts. This arbitrary measure of bout frequency on the control sessions accurately represented each animal's drinking behavior since the interval between consecutive drinks was usually other only a few seconds or at least several minutes.

Each fixed interval was divided into 10 equal segments for the purpose of recording the drinking and key-pecking patterns. The drinks and key pecks which occurred in each of these segments were recorded on different counters.

Results

Each animal's drinking is described in Fig. 1 in terms of the mean sessional water intake, mean bout frequency, mean bout duration, and mean intake rate. The mean sessional water intake equals the product of the latter three parameters. The data are presented separately for each of the three experimental conditions (open symbols) and for the nonscheduled control condition (filled symbols). Each open symbol in Fig. 1 represents the mean of ten experimental sessions, except that for S3 data were collected from only nine sessions under the FI 100-sec and FI 200-sec schedules. Each filled symbol represents a mean o the last 25 control sessions for S1 and S3, and of the last 24 control sessions for S2. No results are reported for the control sessions priding the initial experimental condition (FI 100-sec) because only partial data were obtained during these sessions.

As shown in Fig. 1, the animals typically drank 10-20 ml of water per session. Water intake was directly related to food reinforcement rate for each animal. Each drank significantly more (independent samples *t*-test, one-tailed) under the FI 50-sec schedule than under the FI 100-sec schedule, $t(18) = 3.01$, $p < 0.01$; $t(18) = 2.68$, $p < 0.01$; and $t(17) = 6.35$, $p < 0.01$ for animals S1; S2; and S3, respectively, and S1 and S3 also drank significantly more water under the FI 100-sec schedule than under the FI 200-sec schedule, $t(18) = 2.65$, $p < 0.01$; $t(18) = 0.98$, $p > 0.1$; and $t(16) = 1.98$, $p < 0.05$ for animals S1; S2; and S3 in order. Since all experimental sessions were of equal duration, food reinforcement rate and total time of access to food were confounded. It is

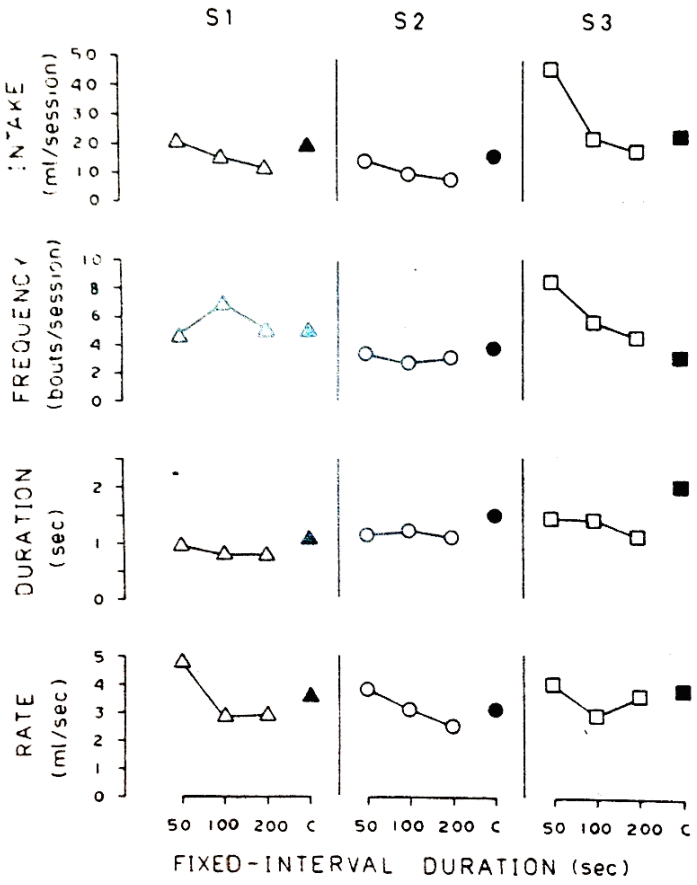

Fig. 1. Mean sessional water intake, mean sessional bout frequency, mean bout duration, and mean intake rate for each animal: S1, S2, and S3. Open symbols represent observations from the experimental conditions: FI 50-sec, FI 100-sec and FI 200-sec. Filled symbols represent observations from the control (C) sessions.

not, therefore, possible to state whether the differences in total water intake across conditions are attributable to differences in total food intake (food-induced) or in the distribution of food presentation (schedule-induced).

Sessional food intakes were matched for the FI 50-sec schedule and the nonscheduled control condition, allowing the determination of whether any of the animals exhibited schedule-induced drinking under the FI 50-sec schedule. Sessional water intake under the FI 50-sec schedule was the same, less, and more than that under the control condition for animals S1, S2, and S3, respectively, $t(18) = 1.43$, $p > 0.1$; $t(18) = 3.79$, $p < 0.01$; and $t(18) = 6.59$, $p < 0.01$ for S1; S2; and S3. Only S3 drank much more water under the experimental condition than under the control condition, with sessional water intake reaching an asymptotic level of 51 ml on the fourth session. This was the only instance in which water intake or total drinking time increased across sessions within an experimental condition.

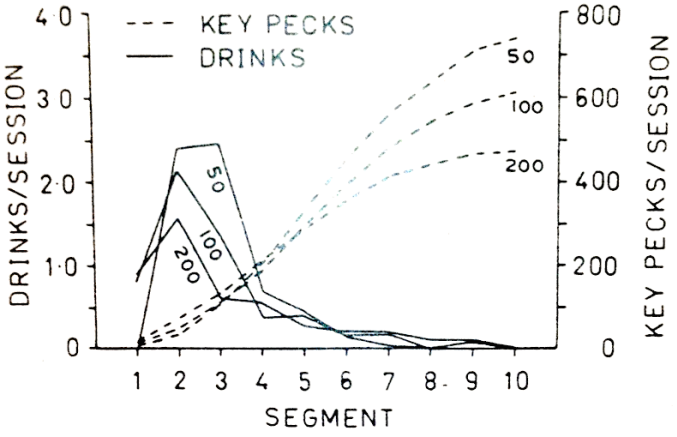

Fig. 2. Group mean drinks/session (solid lines) and key-pecks/session (broken lines) for the FI 50-sec, FI 100-sec and FI 200-sec conditions. Each fixed interval was divided into ten equal segments in order to present the response patterns. Each observation indicates the total number of responses (key-pecks or drinks)/session which occurred within a particular tenth of the fixed interval.

The three animals exhibited similar drinking characteristics (Fig. 1). Each drank on a low proposition of intervals: On less than 7%, 12% and 17% of the intervals under the FI 50-sec, FI 100-sec and FI 200-sec schedules, respectively. Moreover, only S3 drank consistently more often on the experimental sessions than on the control sessions. The animals rarely drank more than once during an interval (mean of 1.08 drinks/bout). The mean bout durations for each animal were brief and were similar under each experimental condition (mean of 1.09 sec), although they were slightly longer under the control condition (mean of 1.50 sec). All animals drank at high rates under the experimental conditions (mean of 3.35 ml/sec) and under the control condition (mean of 3.46 ml/sec). All three animals drank faster under the FI 50-sec schedule than under the FI 200-sec schedule, but only S2 showed a direct relation between drinking rate and reinforcement rate.

The group mean sessional drinking patterns (solid lines) and the group mean sessional key-peck patterns (broken lines) for each experimental condition are shown in Fig. 2. The intervals in each experimental condition were divided into ten equal segments for the purpose of recording these patterns.

The animals drank early in the fixed interval and pecked the response key towards the end of the interval. The time at which drinking bouts were initiated was directly related to the duration of the imposed FI schedule: Drinking began an average of 12 sec, 22 sec, and 50 sec after food presentation under the FI 50-sec, FI 100-sec and FI 200-sec reinforcement schedules, respectively (averaged across animals).

The group mean drinking rates (frequency/session) and key-peck rates were directly related and increased as the FI duration decreased, i.e., as the food presentation rate increased. Moreover, the maximal drinking and key-peck rates were directly related for each animal. The maximal

drinking rates were those in segments 1-3 of the fixed interval and the maximal key-peck rates were those in segments 8-10 of the fixed interval.

Discussion

The above results show that, under foo-reinforced FI schedules, pigeons' concurrent drinking is usually rapid (3-4 ml/sec), although the drinking bouts are brief (0.8-1.4 sec) and infrequent (occurring on 5-15% of intervals). These drinking characteristics are strikingly different from those exhibited by rats tested under fixed-interval or fixed-time food reinforcement schedules with durations of 1-4 min. Rats exposed to such schedules drink at rates of only 0.02-0.05 ml/sec [9,17], but their mean bout durations are 10-50 sec long [9,12,17,21] and most of the animals drink on 80-100% of the intervals [5,7,9,21]. Thus, while the pigeons in the present experiment drank about one hundred times faster than rats are reported to drink, their drinking bouts were 10-50 times shorter and 5-10 times less frequent than those typically reported for rats.

Given such large differences between the parameters describing drinking in rats and in pigeons, it is not necessarily surprising that pigeons have generally failed to exhibit schedule-induced drinking [8,15,25,27]. The development of schedule-induced drinking in the pigeon may be restricted by limitations in kidney function [10] or by the degree to which drinking is associated with, or elicited by, eating [28]. In particular, none of the pigeons in the present experiment, with the exception of S3 on the FI 50-sec schedule, increased their mean bout frequencies or durations across sessions within an experimental condition. Rats exposed to intermittent food presentations avidly increase both the frequencies and durations of their drinking bouts [20], although the mean water intake per bout eventually stabilizes and appears to be orally monitored and regulated [9,12]. The finding that polydipsia is reliably induced in rats, but not in pigeons, exposed to FI food reinforcement schedules seems to depend on the fact that rats, but not pigeons, increase their drinking frequencies and tend to drink after virtually every food presentation.

Finally, pigeons are not the only species in which schedule-induced drinking has been difficult to obtain. Hamsters [26], gerbils [4,26] and guinea pigs [14,18,24] generally do not develop polydipsia under conditions which quickly produce such drinking in the rat. Wilson and Spencer [26] suggested that hamsters may fail to develop schedule-induced polydipsia because they have a different "pattern of water regulation" (p. 865) than animals which do show schedule-induced drinking. For example, hamsters and gerbils become polydipsic when food deprived instead of reducing water intake as do guinea pigs and rats [13] and rhesus monkeys [19]. Since pigeons exhibit a food-deprivation induced reduction in drinking [28], it appears likely that different variables are responsible for the difficulty in obtaining schedule-induced polydipsia in hamsters and gerbils, on the one hand, and pigeons, on the other. It will be worth examining the differences in drinking characteristics between those species which exhibit schedule-induced polydipsia and those species which do not: Such differences should help to identify the factors responsible for this phenomenon.

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