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AN EXAMINATION OF THE STRENGTH AND LOCUS OF INTERIM ACTIVITIES DURING PERIODS OF NONREINFORCEMENT ON VARIOUS SIMPLE AND MULTIPLE SCHEDULES OF FOOD REINFORCEMENT

by

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of the requirements for the degree of
Doctor of Philosophy

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ABSTRACT

Three experiments were conducted to investigate Staddon's account of interim activities as induced behaviors which occur at times when a reinforcer is unlikely to be delivered (S^- times). These experiments examined Staddon's S^- interpretation of interim behavior by studying drinking and wheel running on various simple and multiple schedules of food reinforcement.

Experiments 1 and 2 were concerned with Staddon's contention that drinking is a representative interim activity which is occasioned by the unavailability of food rather than by the presence of food per se or its ingestion. Contrary to other accounts of schedule-induced polydipsia, this interpretation infers that the link between eating and drinking is not essential for the induction of drinking. In Experiment 1, three rats were exposed to a series of multiple schedules to determine whether drinking occurs during S^- times that are signalled by events other than food ($S^-_{nonfood}$) or is confined to S^- times signalled by the occurrence of food (S^-_{food}). Each multiple schedule consisted of a food component, in which reinforcement was delivered on either a fixed or random-interval schedule, and an extinction component, a period when food never occurred. In Experiment 2, drinking was compared in four independent groups of rats exposed to simple or multiple variable-interval or random-interval schedules.

The results of Experiments 1 and 2 indicate that drinking does not occur during an $S^-_{nonfood}$ even if it predicts the nonoccurrence of food just as well as an S^-_{food}. In all instances, drinking was restricted to S^-_{food} occasions with very little drinking during the $S^-_{nonfood}$

extinction component of any multiple schedule. The results also suggest that interim activities differ in the extent to which they can be allocated to S^{-}_{nonfood} times. For example, consistently higher levels of wheel running occurred in the extinction component compared to the food component of the multiple schedules.

Behaviors that can be induced by S^{-}_{nonfood} occasions are particularly important for Staddon's account of contrast since the effect depends, according to the time allocation model, on the reallocation of interim activities from the food to the extinction component of a multiple schedule. Experiment 3 attempted to assess the interactive effects of these differences in the functional properties of drinking and wheel running by using a prototypical contrast paradigm with drinking, wheel running and bar pressing activities simultaneously available. The findings indicate that contrast effects occur not only in terminal behavior, but that other nonterminal activities such as drinking, can be similarly affected.

The implications of these results for Staddon's account of interim behavior and the time allocation model of contrast were discussed.

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In 1971 Staddon and Simmelhag published a highly controversial and influential paper. The paper reported an experiment using Skinner's 1948 superstition procedure. Naive pigeons were initially trained to approach and eat from a feeder and then exposed to daily sessions in which the feeder was briefly presented every 12 seconds. Detailed and systematic recordings were made of the frequency and order of behavior occurring throughout the interval between food deliveries. By using this method of analysis Staddon and Simmelhag were able to demonstrate that a regular sequence of activities occurred between food deliveries for each bird. Some responses such as pecking and orientation toward the feeder occurred most frequently in the later portion of the interval just before the delivery of food. Staddon and Simmelhag proposed that these responses were instances of a broader class of behavior which occurs in the presence of or are directed toward stimuli that are highly predictive of food or some other reinforcer. They called such behavior <u>terminal activity</u>. A variety of other activities preceded these responses within the interfood interval. Early in the interval, pigeons engaged in activities such as circling, wing flapping and preening. According to Staddon and Simmelhag, this behavior was part of a separate class of activities which occur at times when food or some other reinforcer does not occur. They called such behavior <u>interim activity</u>.

Staddon and Simmelhag introduced the terms "interim" and "terminal" to call attention to the differences between behavior that occurs early and late in the interfood interval. These terms have been adopted by a great many investigators and will also be used in this thesis.

Although Staddon and Simmelhag (1971) provided an account of both interim and terminal behavior, many of Staddon's subsequent papers (Staddon & Ayres, 1975; Staddon, 1977b) focus on interim activities. Terminal activities are discussed primarily in the ways they interact with interim behavior on schedules of reinforcement. The study of animal learning was influenced in several ways by Staddon's account of interim behavior. In 1971, the account was useful in providing a theoretical framework relating effects previously seen as independent or only vaguely related. Several historically distinct behaviors (e.g., schedule-induced behavior, displacement activities, adjunctive behavior) were grouped together within the interim class on the basis of similar functional properties, probable causal factors and adaptive roles.

In addition, Staddon's account of interim behavior can be regarded as instrumental in changing the traditional focus in operant conditioning research. Typically in an operant conditioning experiment, a single activity is selected as the instrumental response and it is then studied in isolation from all other behavior. The results of Staddon and Simmelhag's experiment suggested that the traditional emphasis on a single aspect of behavior was misplaced. Their analysis clearly demonstrated that other activities were produced by operant conditioning procedures, and that these activities were as vigorous as the instrumental response. More recently Staddon (1977b) has suggested that interim activities provide the key for understanding many puzzling findings in the operant literature. For example, Staddon (1979; in press) has described a research strategy that incorporates the study of interim behavior with that of the traditional operant to examine generalization - gradient peak shift and properties of inhibitory generalization gradients. Similarly, Hinson and Staddon (1978) have used the concept of interim behavior to provide a novel explanation of behavioral contrast. It seems therefore, that Staddon's notion of interim behavior is important not only theoretically but also empirically, for it has suggested a number of novel experiments and provided explanations for some unanswered questions in the field of behavior analysis.

The properties of interim activities as they are outlined in Staddon's account are summarized in the following three assertions, which will be discussed separately:

(1) Interim activities occur at times when a reinforcer is unlikely to be delivered (S^- periods).

(2) The periods identified as interim and their associated activities correspond to motivational states.

(3) Interim activities are schedule-induced.

Interim Activities and S^- Periods

Staddon and Simmelhag (1971) stated that the definitive characteristic of interim behavior is that it occurs at times or in the presence of stimuli that signal the absence of food (S^- times). In interval schedules, the interim period comprises the early seconds of the inter-reinforcement interval when food has just occurred and is not due to occur again for some time. In the Staddon and Simmelhag study, interim behaviors such as circling away from the feeder occupied the initial 6 or 7 seconds of the FT 12-sec schedule. Rats typically drink early in the interval after food on similar schedules (Staddon & Ayres, 1975). Very little drinking occurs in the later two-thirds of the interval under normal unrestricted conditions. In contrast, terminal behavior tends to occur during S^+ occasions, such as the final seconds of interreinforcement intervals when food is imminent.

Staddon's account of interim behavior seems to be an accurate description of the temporal distributions of some well-known non-terminal activities, such as pigeons' circling away from the feeder and rats' polydipsic drinking. There are, however, indications that some activities that have traditionally been described as "adjunctive" do not fit Staddon's criterion of occurring exclusively in the early seconds of interreinforcement intervals. Behavior such as wheel running (Levitsky & Collier, 1968), nitrogen licking (Taylor & Lester, 1969), and air licking (Mendelson & Chillag, 1970) all tend to occur throughout the interval rather than being confined to the first few seconds after food delivery as is usually the case with drinking. Furthermore, when opportunities for drinking and running are concurrently available, drinking typically follows eating while running follows drinking (Segal, 1969; Staddon & Ayres, 1975). There is also some evidence that running occurs comparatively late in interreinforcement intervals even if drinking is not a potential competing activity (Mann, 1977; Skinner & Morse, 1958). Wheel activity differs further from drinking in that it often follows or alternates with unreinforced lever pressing (Smith & Clark, 1974).

These results suggest that the temporal distributions of interim activities are not as uniform as Staddon's descriptions suggest. Some of these activities (e.g., drinking) occur only in the early portions of the interval, while others (e.g., running) occur throughout the interval. Perhaps non-terminal activities should be divided into two subclasses; those that occur immediately after food and those that can also occur during nonreinforcement times later in the interval. Staddon (1977b) seemed to acknowledge such a possibility when he discussed these differences in temporal distributions and proposed the term "facultative" behavior to distinguish activities such as wheel running that can occur later in the interval, often between bouts of activities such as polydipsic drinking and terminal activities such as lever pressing. The facultative behavior concept has not been well-developed, however, and Staddon's present position (e.g., Hinson & Staddon, 1978) seems to be that "interim behavior" is a term that applies to non-terminal behavior that may occur at various times in interreinforcement intervals when food is not clearly imminent.

Interim Activities and Nonfood Motivational States

Staddon (1977; Staddon & Simmelhag, 1971) also proposed that S^- times and S^+ times produce interim and terminal motivational states that define the potential repertoire of interim and terminal activities. Terminal activities, according to Staddon, are related to the scheduled reinforcer. Hence, late in the interval, animals stand near the site of food and perform food-related activities. Rats, for instance, contact the food cup (Reberg, Mann & Innis, 1977) and pigeons peck with a distinctive food-related topography (Reberg, Innis, Mann & Eizenga, 1978).

Different activities occur in the early seconds of the interval when animals usually move away from the food site and perform activities unrelated to food. Rats, for example, display polydipsic drinking at such times and pigeons perform activities such as circling away from the food site. According to Staddon, these interim activities are associated with a nonfood motivational state. Although there are strong indications that Staddon's account does not apply to all reinforcers, (Mann, 1977; Reberg, Innis & Eizenga, 1978; Reberg, Mann & Innis, 1977), it appears to be an accurate description of activities in periodic food schedules.

More than one reinforcer (other than food) may be effective during the interim period. Consequently interim behavior can consist of many different activities which include drinking, running, licking at a stream of air, gnawing, tail-nibbling, grooming, head and body movements, shredding paper or attacking a conspecific (see reviews by Falk, 1971; Staddon, 1977b). Staddon and Ayres (1975) studied this matter directly when they exposed rats to FT schedules of food delivery in a hexagonal enclosure that permitted a variety of activities other than eating. Several other experiments have been conducted using similar procedures (Mann, 1977; Roper, 1978). In such experiments, an interesting question arises as to the determinants of the activity which develops in any particular case. One possibility is that any activity within the animal's repertoire can expand to occupy the time made available by any schedule. Alternatively, certain activities may be preferentially linked to certain schedules, reinforcers and/or species (Hogan & Roper, 1978; Mann, 1977). A related question is whether different acitvities can substitute for one another. For example, if airlicking is prevented in the hexagonal enclosure will other activities take its place? More research is needed to adequately answer these important questions.

Interim Activities and Induction

In some instances, Staddon (1977b) uses the term interim to refer "to all those activities which precede the terminal response within the interfood interval" (p. 134). At other times, interim activities are defined as "induced behaviors which occur at times when a reinforcer is unlikely to be delivered" (Staddon, 1977b, p. 126). According to Staddon (1977b) either usage is permissable providing that it is clear which usage is intended.

Induced behavior as defined by Staddon includes only those activities which are facilitated by the schedule as compared to a baseline condition when the schedule is not in effect. Ideally, of course, the facilitative effects of the schedule are measured in comparison with pre- and post-schedule baselines. Polydipsic drinking is an obvious example of an induced interim behavior. In a 3.17 hour session, Falk (1961) reported that rats consumed approximately 3 or 4 times their normal daily intake of water.

Staddon (1977b, p. 126) coined the term facultative to refer to "activities that occur during the schedule but do not appear to be directly affected by schedule factors" (i.e., are not induced). As previously mentioned, wheel running is an example of a facultative behavior which is not schedule-induced but which precedes the terminal response within the interfood interval (Staddon & Ayres, 1975).

Although there is good evidence that a variety of interreinforcement activities occur during periodic schedules of food reinforcement, only one activity, polydipsic drinking has been studied in depth. In the absence of information on a variety of combinations of species, reinforcers, and behaviors, Staddon's account of interim behavior, as summarized in this chapter, has necessarily relied on studies of induced drinking. Indeed, drinking is often regarded as a prototype of all interim behavior by researchers in this area (Christian, Schaeffer & King, 1977). Since drinking has captured more experimental attention than any other interim behavior and is also the behavior examined in all three experiments to be reported in this thesis, the remainder of the introduction is devoted to a review of the literature on schedule-induced polydipsia (SIP).

CHAPTER II

Schedule-Induced Polydipsia

Polydipsia is a robust and reliable phenomenon. According to Staddon and Simmelhag (1971), drinking is a representative interim behavior. As discussed in Chapter 1, interim behaviors (a) are induced by the schedule, (b) associated with motivational states incompatible with the terminal reinforcer, and (c) occur during S^- periods of non-reinforcement. This chapter examines polydipsic drinking in terms of these three properties of interim behavior.

Polydipsia and Induction

One of the most striking features of SIP is its excessiveness. As previously mentioned, there are Falk's comparisons between SIP and daily intake. Falk (1961) reported that rats consumed three to four times their normal daily water intake in a 3.17 hour session of periodic food deliveries. The quantity of water ingested on a schedule of intermittent food reinforcement has also been compared to the amount consumed on a variety of baseline conditions with no food available (Staddon & Ayres, 1975) or with equivalent amounts of food presented in one feeding at the beginning of a session (Mann, 1977). Although not too many experiments have made comparisons of SIP with pre- and post-schedule baselines when no food is delivered, most of the available data clearly indicate that SIP is indeed an induced activity. In fact, there is little dispute about the induced nature of SIP.

Polydipsia and Nonfood Motivational States

There is at least some evidence in support of Staddon's contention that SIP is representative of a non-food motivational state. Staddon (1977b) has argued that "not only does the rat drink during the interim period, but its state resembles thirst" (p. 138). He draws several rather convincing parallels between SIP and physiological thirst to support his argument. For example, the acquisition of induced drinking is hampered by pre-loading the rat with water. Rats and monkeys learn to press a lever to obtain access to water during the interim period (Falk, 1971). In addition, the rate of drinking is directly related to the palatability of the liquid and if the terminal food reinforcer contains water, less drinking is observed.

One obvious question in this regard is whether an animal would interrupt a bout of SIP to eat a surprise food pellet. Although there are no detailed data, there are indications that brief test presentations of food during the interim period may, as Staddon predicts, fail to elicit eating (Konorski, 1967). However, in a recent experiment by Reberg (1980) on the reinforcement of SIP, animals stopped drinking when a "surprise" pellet arrived and then returned to the bottle. Although definitive tests are lacking, there seems to be at least some support for Staddon's non-food motivational account of SIP.

Polydipsia and S^- Periods

According to Staddon and Simmelhag (1971) drinking, like other interim behavior, is induced by S^- periods of nonreinforcement. Staddon and Simmelhag's views contrasted sharply with previous attempts to explain polydipsic drinking. In the earlier accounts drinking was regarded as a behavior with unique dynamic properties that set it apart from all others. This was at least partially a result of the fact that in most of these explanations, drinking was hypothesized to be elicited by factors associated with the ingestion of a food pellet. The simplest explanation proposed that drinking resulted from a normal tendency of rats to drink after eating (Kissileff, 1969; Lotter, Woods & Vasselli, 1973; Stein, 1964). Another version suggested that drinking resulted from a specific physiological deficit which was produced by ingestion of a dry food pellet (Teitelbaum, 1966). In all instances, drinking was regarded as a food-elicited behavior. Staddon's (1977b) interpretation suggested that the onset of drinking was occasioned by the unavailability of food at post-pellet times rather than by the presence of food per se or its ingestion. Contrary to food-elicition explanations, this interpretation infers that the link between food ingestion and drinking need be neither strong nor unmodifiable. Accordingly, Staddon proposed that drinking, like all other interim behavior, need not be tied to post-food periods but may occur at other times or in the presence of a variety of stimuli that signal the absence of food. It is therefore appropriate to consider in some detail the evidence for polydipsic drinking during S^- periods other than those that are initiated by a food pellet in the early portion of the inter-reinforcement interval.

Several different experimental manipulations have been used to determine whether or not the occurrence of drinking is dependent upon the presence of food. These investigations can be divided into two categories: (a) those that examine second-order schedules to determine if drinking occurs after a nonfood S^- and (b) those that disrupt the usual sequence of eating/drinking by restricting access to water or omitting food. The eat/drink sequence that typically occurs in most experimental investigations of polydipsia is crucial according to food-elicition explanations of polydipsia but not to Staddon's account of drinking as an instance of an interim activity. His account clearly implies that drinking should occur in S^- periods that are signalled by events other than food.

(a) Drinking on second-order schedules

As we have seen, there are two classes of explanation for SIP: drinking may be elicited by stimulus factors associated with the ingestion of a pellet (food-elicited behavior) or it may be induced by the discriminative properties of pellet delivery that signal a period of low reinforcement probability (S^- behavior). On most simple schedules these two possibilities are confounded because the S^- nonreinforcement time (early portion of the interval) is initiated by a food pellet.

Second-order schedules have been used by investigators to experimentally separate these two alternative explanations. On a second-order schedule an animal is typically required to complete a series of fixed-intervals (FI). For instance, on a FR3 (FI 1 min) schedule, primary reinforcement (food pellet) is contingent upon completion of three successive FI components. A response at the end of the third interval produces food accompanied by a briefly-presented stimulus. Responses completing the first and second intervals produce the stimulus alone. If drinking occurs after a nonfood stimulus on a second-order schedule, this suggests that drinking is not simply a post-food behavior. This outcome would therefore challenge so-called post-prandial interpretations of drinking as a requirement to eliminate the oral effects of each pellet (Stricker & Adair, 1966) and support Staddon's assertion that drinking is simply an instance of "interim activity" that occurs during times when reinforcement never occurs.

Rosenblith (1970) reported the first study of drinking using a FR 3 (FI 1 min) second-order schedule. As expected, drinking regularly followed eating. However as training progressed, each rat also began to drink following presentation of the stimulus alone. The two types of drinking differed, however, in that post pellet drinking tended to occur at high rates in long uninterrupted bouts, whereas the drinking that followed the nonfood stimulus was interrupted frequently by lever pressing and occurred at a much lower rate. A similar pattern of drinking was observed in two other studies (Porter & Kenshalo, 1974; Wuttke & Innis, 1972). There have also been failures to obtain drinking after a nonfood stimulus. Two of three rats in an experiment by Porter, Arazie, Holbrook, Cheek and Allen (1975) failed to drink following a nonfood stimulus.

A second-order schedule may be arranged so that either a fixed number or a variable number of fixed-intervals are required to complete the schedule. Variable second-order schedules are commonly called percentage reinforcement schedules. For example, on a 90% reinforcement schedule, 90% of the food assigned by the FI is actually delivered, while the remainder is omitted on a random basis. In an experiment by Porter et al. (1975) drinking time was compared during sessions in which every fixed interval ended with food delivery (100% condition) to those in which only 90% of the intervals ended with the delivery of a pellet. Negligible licking followed the briefly presented stimulus which ended nonreinforcement intervals; instead, a substantial increase in lever pressing occurred. Porter et al. attempted to eliminate bar pressing following the nonfood stimulus by retracting the lever for the first 30 seconds of each interval. The retraction procedure produced no increases in drinking either after food or after the nonfood S^-.

Allen, Porter and Arazie (1975) found similar results when rats were exposed to a variable second-order schedule in which the percentage of intervals ending in reinforcement was varied in steps from 100% to 10%. Drinking rarely followed the nonfood stimulus, even though in this experiment a substantial pause in lever pressing was observed in both food and stimulus initiated intervals. As in the former experiment, all rats drank at polydipsic rates following the delivery of food.

In summary, second-order schedules have produced only limited evidence for Staddon's position that drinking is representative of a class of interim behavior that occurs during nonfood S^- occasions. In the experiment by Rosenblith (1970) and Wuttke and Innis (1972) using second-order schedules with a fixed number of components, a total of four rats were observed to drink following a nonfood stimulus. In the Porter et al. (1975) experiment, however, two rats did not drink. Consistently negative results were reported for rats on variable second-order schedules. A total of nine rats in experiments by Allen et al. (1975) and Porter et al. (1975) failed to drink following a nonfood stimulus on such schedules; in all these experiments, drinking that could reasonably be described as polydipsic or excessive occurred only following the delivery and ingestion of a food pellet. Drinking after a nonfood stimulus was, in comparison, a weak and unreliable phenomenon. Thus, although the second-order schedule research provides limited support for drinking as an activity during S^- times signalled by stimuli other than food, there can be little doubt that the phenomenon is much more robust when preceded by food.

(b) Restricted access studies of drinking

Polydipsia is typically regarded as a post-pellet phenomenon with very little or no drinking occurring in the later two-thirds of a fixed interpellet interval under normal unrestricted conditions. Restricted access experiments have examined the effects of limiting the availability of water to different portions within the interpellet interval. Food-elicition explanations of drinking predict that restricting the availability of water to times remote from food delivery should eliminate or reduce drinking. Staddon's account, on the other hand, predicts that drinking should occur as long as the opportunity to drink exists during an S^- time.

Flory and O'Boyle (1972) trained rats to respond on one lever for water (FR1 schedule) and on another for food delivery on a FI 1 min schedule. The pattern of behavior that developed was typically one in which the rats bar pressed for water for some time immediately after each food pellet. When periods of water unavailability were successively inserted in the first, second, third and fourth quarters of the 1-min fixed-interval food schedule, all rats continued to drink although water intake was slightly reduced when compared to the control conditions of continuous water availability. Gilbert (1974) used a similar procedure except that in this experiment rats were not required to lever press to obtain water. When the drinking tube was freely available, the rats drank in the usual post pellet pattern with bouts occupying the first half of the interval. When the drinking tube was only available in the later half of the interfood interval, drinking was initially disrupted and only gradually recovered to levels approximating those observed early in the interval.

In summary, it seems clear that rats can transfer well established drinking from post-food times to parts of the interval remote from food delivery. In experiments using restricted access procedures, drinking is sometimes attenuated but not eliminated. There remain, however, several unanswered questions in this area of research. It is unknown, for example, whether drinking would develop under conditions of restricted access since the present experiments have only examined the transfer of well established drinking to parts of the interval remote from food delivery. These experiments also lack detailed comparisons of drinking that occurs under free and constrained conditions. For instance, Flory and O'Boyle (1972) reported relatively little change in patterns of bar pressing for food in conditions where water was available only in the later portion of the interval, thus suggesting that drinking later in the interval may have alternated with unreinforced lever pressing. Drinking early in the interval typically occurs in long uninterrupted bouts, beginning after eating and ending with the initiation of unreinforced lever pressing (Smith & Clark, 1974). There may be other important differences in drinking that occurs early and late in the interpellet interval.

On the surface the preceding results may seem contradictory to Staddon's (1977b) account of interim behavior as activities which occur in the early (S^-) portion of interreinforcement intervals. However, Staddon has suggested that in limited availability procedures the presentation of the water bottle signals a period when food will not occur.

If one accepts this assertion, the results of these experiments are consistent with the notion that induced drinking is characteristic of interim periods (S^- times). In addition, they indicate that such periods need not be defined temporally or be initiated by food.

Other experiments supporting S^- interpretation of drinking

Additional evidence suggesting the importance of S^- times for the induction of drinking comes from two experiments. Keehn and Colotla (1970) conducted a study which showed that drinking is occasioned by the unavailability of food during the post-pellet period rather than by the presentation of food. In this experiment continuous reinforcement (CRF) was programmed for a variable number of responses at the end of one-min fixed intervals. Drinking typically occurred after all the pellets were consumed on the schedule rather than after each individual pellet delivery in the CRF sequence. When food became unavailable, animals began drinking. More specifically, the stimulus for the onset of drinking was the absence of a pellet following a bar press. If food alone elicited drinking one might expect short bouts of licking after each pellet in the CRF sequence.

Another study (Millenson, Allen & Pinker, 1977) examined the importance of periods of low probability of reinforcement for the induction of drinking. Millenson et al. studied drinking and lever pressing patterns of rats exposed to either an arithmetic series or random variable-interval reinforcement schedule. On the variable-interval schedule with an arithmetic progression of intervals, the probability of food increased as a function of post-food time. Thus on this schedule the probability of food was relatively low (but not zero) in the immediate post-food period. As predicted by Staddon's account, post-pellet drinking was observed in all the VI animals. Lever pressing rates were low for the first 20 secs after reinforcement, and increased as time from the last pellet elapsed.

On a truly random-interval (RI) schedule, lever pressing is expected to occur with a constant probability throughout the inter-reinforcement interval (cf. Catania & Reynolds, 1968). According to Staddon's account, drinking should be less reliably obtained on a random interval (i.e., constant probability) schedule because the post-pellet interval is not an occasion that reliably signals the nonoccurrence of food. Millenson et al.'s data supported this prediction with most of the RI animals drinking less than 10 ml of water in a session. Drinking that occurred on the RI schedule was as likely at any one post-reinforcement time as another. Lever pressing rates were low for the first 10 secs after food but thereafter responding occurred at a constant rate. These differences in the amount and pattern of drinking on the VI and RI schedules can be explained within Staddon's account of drinking as characteristic of interim S^- periods. Moreover, these results indicate that drinking is dependent on more than a simple link between eating and drinking.

In summary there is at least some evidence for Staddon's S^- interpretation of drinking. Polydipsic drinking is less reliably obtained when food is presented on a CRF schedule (Keehn & Colotla, 1970) or on a RI schedule of reinforcement (Millenson et al., 1977). In conjunction with stressing the importance of S^- periods for the induction of drinking, Staddon's account clearly implies that drinking should occur in S^- periods that are signalled by events other than food. According to Staddon (1977b), the link between eating and drinking is not essential for the induction of drinking. Although there is evidence that the link between eating and drinking can be modified somewhat within the inter-food interval, there are no clear indications of polydipsic drinking during S^- occasions that are disassociated from food. Thus the question of whether rats drink during S^- periods that are signalled by events other than food remains unresolved.

The experiments reported in this thesis examined Staddon's S^- interpretation of interim behavior by studying drinking on different schedules of positive reinforcement. In the next chapter, a simple experiment is described which examines more directly the question of whether drinking occurs during S^- periods that are signalled by stimuli other than food.

CHAPTER III

EXPERIMENT 1

Interim Activities and S^- Periods

Polydipsic drinking reliably occurs shortly after the ingestion of a food pellet on a variety of fixed or variable interval schedules. Staddon (1977b) has suggested that drinking is induced by the unavailability of food at such times rather than by the presence of food per se or its ingestion. According to Staddon, drinking, like all other interim behavior, need not be tied to post-food periods but may occur at times or in the presence of a variety of stimuli that signal the absence of food (S^- times). Although several different experimental manipulations have been used to determine whether or not the occurrence of drinking is dependent upon the presence of food, the question of whether drinking occurs during S^- times that are signalled by events other than food remains unanswered.

In Experiment 1, drinking was examined in three rats exposed to a series of multiple schedules of food reinforcement. In the initial condition of Experiment 1, rats were exposed to a multiple FI/Extinction schedule. According to Staddon's account, drinking should occur during any occasion that signals the nonoccurrence or unavailability of food. The fact that drinking typically occurs after food on interval schedules is thus a product of food becoming the most reliable and salient signal for a food-free period, rather than the nonassociative effects of food consumption per se. According to Staddon's account, polydipsia levels of drinking should occur after food in the FI component of the multiple schedule. The extinction component of the multiple schedule should also induce drinking. However, if one assumes that interim behaviors are associated with the most salient S^- time or that animals given a choice between two S^- times prefer to drink in a food-initiated period, then little drinking could occur during the extinction component of a mult FI/EXT schedule without necessarily damaging Staddon's account.

The question of greatest concern is what happens to drinking when the food → no food contingency implicit in the FI schedule is eliminated by changing to an RI schedule of reinforcement. Staddon suggests that interim drinking results from a negative contingency that prevails when a stimulus signals a period in which food never occurs: a food → no-food contingency, for example (where food deliveries signal a period in which food never occurs) or a light → no-food contingency (where light signals the unavailability of food). Now, in a mult RI/EXT schedule, food is <u>not</u> a reliable S^-, because the RI schedule programs at least some intervals in which one food delivery is immediately followed by another food delivery. Instead, the most reliable S^- in a mult RI/EXT schedule is the stimulus that signals extinction. Staddon's account therefore predicts that drinking should occur primarily during the extinction component of the mult RI/EXT schedule. Such a result might also be expected from an experiment by Hinson and Staddon (1978) which showed that running occurs during an extinction component of a multiple schedule. However, if rats do not drink during the extinction component of a mult RI/EXT schedule, Staddon's account of drinking as an interim behavior that occurs during S^- periods would be called into serious question.

METHOD

Subjects

The subjects in the main experiment were three male Long Evans hooded rats, approximately 150 days old and bred in the laboratory. The rats were reduced to 75% of their ad lib weights and maintained at those weights throughout the experiment by adjusting their post-session ration of Purina Rat Chow. Three additional male hooded rats of the same strain (but obtained from Quebec Breeding Farms) served as subjects in a subsequent experiment (Experiment 1a) intended to provide information about possible nonassociative effects of stimuli used in the main experiment. All rats were individually housed with unrestricted access to water.

Apparatus

The apparatus was a response chamber (inside dimensions: 23 cm x 20.5 cm x 19 cm) with two side walls and a top made of Plexiglas. The end panels of the box were aluminum. The floor was 18 evenly-spaced stainless steel bars. Centered on one end wall, 3 cm above the grid floor was a feeder opening (4.5 cm x 4.5 cm) covered by a pin-hinged Plexiglas door. This door pushed open into a feeder box (inside dimensions: 5.0 cm x 4.5 cm x 5.5 cm). Movement of the door was recorded by a microswitch. A Gerbrands feeder dispensed 45 mg Noyes pellets into the feeder box.

A retractable lever was positioned on the end wall 6.5 cm above the floor and 6 cm to the right of the feeder door. A metal drinking spout that protruded about 1.5 cm into the chamber was located on the side wall 4 cm above the floor and 9 cm to the left of the feeder door.

At the start of the final condition of the experiment, a running wheel 94 cm in radius with a 10 cm entrance, 3 cm from the floor, was attached to the side wall 10 cm to the left of the feeder.

Two 6 W lamps were mounted on a Plexiglas beam centered 9 cm above the chamber. When illuminated, these lamps were turned off briefly every .5 sec creating a flashing light. Masking white noise was continuously present in the experimental room.

Experimental events were controlled and recorded automatically by equipment located in an adjacent room. Contact with the drinking spout was recorded with a Grason-Stadler drinkometer (Model E4690A). Activation of the drinkometer circuit started a clock which continued to cumulate drinking time until .3 sec elapsed with no further contact. The drinking spout was attached to a graduated cylinder that permitted measurement of the quantity of water consumed in a session. Running was defined by closure of either of two microswitches arranged 180^0 apart on the wheel. Time spent running was recorded by a clock which was started by closure of a microswitch and stopped when .5 sec elapsed with no further contact. Postreinforcement pause time was defined and recorded by a clock that started with each food delivery and stopped when the first bar press occurred after food. Another clock cumulated the time between each food delivery and the immediately subsequent feeder door opening. Total time required to complete the session was also recorded. Counters recorded the total number of feeder door openings (nose pokes), licks, and lever presses. The experimental room contained a television camera, to permit observation of unrecorded activities and to monitor the accuracy of devices automatically recording behavior.

Procedure

After preliminary shaping to lever press, the three rats in the main experiment were given 60 pellets on a continuous reinforcement schedule. The animals were then exposed to a series of multiple schedules. Each of these multiple schedules consisted of a food component; in which reinforcement was delivered on either a fixed or random interval schedule, and an extinction period in which food was never delivered.

All three rats were exposed to the following sequence of conditions: mult FI/EXT; mult RI/EXT; mult RT/EXT; mult RI/EXT; mult FI/EXT. On the <u>FI 30 sec/EXT</u> schedule, reinforcement was delivered for each response after 30 sec had elapsed from the last food delivery. This condition was in effect for a total of 20 sessions. The animals were then given 20 sessions on a <u>RI 30 sec/EXT</u> schedule. The RI schedule was arranged by querying a probability gate (BRS/LVE model PB-903/235-11) every 1.5 sec and selecting 5% of these pulses to set up reinforcement. Reinforcer set-ups remained in effect until claimed by a lever press. The schedule was then switched to mult RT 30 sec/EXT, in which a food pellet was delivered every 30 sec independent of behavior. This condition continued for 24 sessions. The animals were returned to RI 30 sec/EXT for 12 sessions and then exposed to a FI 30 sec/EXT schedule for 15 sessions.

At the termination of this condition, the drinking spout was removed from the chamber and the running wheel introduced. The rats were then exposed to 20 additional sessions of a FI 30 sec/EXT (wheel only) condition.

Periods of no food (EXT) were signalled by flashing overhead lights for Rats 1, 2, and 3 in the main experiment. In Experiment 1a, three rats (4, 5, 6) were exposed to a mult FI/EXT condition for 20 sessions where the flashing light signalled the FI component. This permitted assessment of possible nonassociative effects of the flashing light on S$^-$ drinking in the main experiment.

In all of the above conditions, the components of the multiple schedule were 120 sec in duration and strictly alternated. A 7-sec period intervened between the termination of the food component and the onset of the extinction component. This period was intended to prevent the recording of spurious occurrences of activities from the preceding component (e.g., a food pellet that might be delivered during the food component but consumed during the extinction component). During the FI and RI conditions, pellet presentations set up but not collected at the end of a food component were saved and delivered after the first bar press in the next food component.

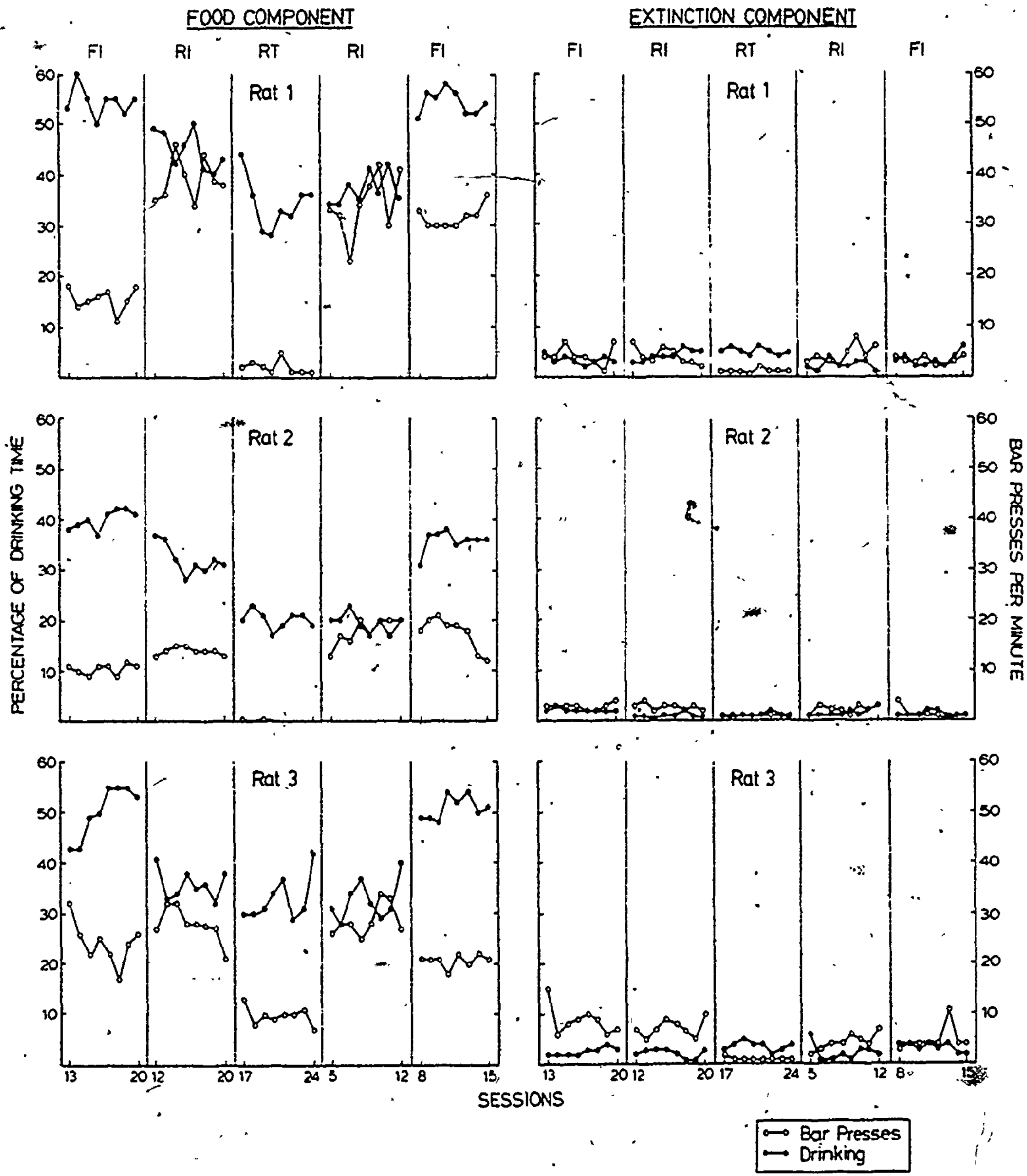
For all rats, the beginning of a session was signalled by the entry of the lever into the chamber. Sessions terminated when all 60 pellets were collected. The lever was retracted when the last pellet was delivered.

RESULTS

Figure 1 shows drinking and barpressing during the last eight sessions of each condition of the main experiment for individual rats. Responding, during the food component of each multiple schedule, is presented in the left panel of the figure and, during the extinction component in the right panel of the figure. The percentage of time drinking (solid circles) was calculated by dividing the overall time spent drinking within each component by the total amount of component

FIGURE 1

Drinking (solid circles) and Barpressing (open circles) for individual rats during the last eight sessions of each condition. Responding during the food and extinction components is shown separately in the left and right panels of the Figure. Experimental conditions were as follows: Phase 1 - Mult FI/EXT; Phase 2 - Mult RI/EXT; Phase 3 - Mult RT/EXT; Phase 4 - Mult RI/EXT; Phase 5 - Mult FI/EXT.


FOOD COMPONENT
EXTINCTION COMPONENT
FI
RI
RT
RI
FI
FI
RI
RT
RI
FI
Rat 1
Rat 2
Rat 3
PERCENTAGE OF DRINKING TIME
BAR PRESSES PER MINUTE
60
50
40
30
20
10
13
20
12
20
17
24
5
12
8
15
SESSIONS
Bar Presses
Drinking

time and multiplying by 100. Bar presses per minute (open circles) were tabulated by dividing the total number of responses by the total component time.

Table 1 summarizes the results of Figure 1 by providing overall averages of the last eight sessions of each condition for drinking and barpressing.

Drinking during the Food Component of each Multiple Schedule

Every rat drank very frequently when the FI schedule was in effect in Phase 1. The average percentage of time spent drinking in this initial phase of the experiment ranged from 39.6% to 53.5% of the component. Each rat spent less time drinking when the schedule was changed to RI in Phase 2. All three rats showed a further reduction of drinking when the RT schedule was imposed in Phase 3. When the RI schedule was reinstated in Phase 4, there were no signs of recovery of drinking to levels shown in Phase 2. However, when the FI schedule was reintroduced in Phase 5, drinking recovered in all three rats to levels approximating those observed in Phase 1. The means for the final 8 days of each phase (Table 1) were submitted to a one way analysis of variance (ANOVA) which indicated a significant overall effect ($\underline{F}(4,8) = 25.97$, $\underline{p} < .01$). Newman-Keuls tests showed further that drinking during each random schedule (Phase 2, 3, 4) was significantly lower than on FI schedules (Phase 1, 5). Comparisons between Phases 1 and 5 (FI) and between Phases 3(RT) and 4(RI) yielded no significant differences. Statistical analyses thus confirm the impression gained from visual inspection of Figure 1 that the FI schedule generated the highest levels of drinking and that there were only weak and inconsistent differences in the levels of drinking produced by RI and RT schedules. Although drinking was substantially

TABLE 1

Percentage of Drinking Time, Bar Presses Per Minute, Pause Time per Pellet for each Rat. Data are Means over Eight Sessions at the End of the Conditions

	FOOD COMPONENT					EXTINCTION COMPONENT				
	Percentage of Drinking Time									
Rat	FI/EXT	RI/EXT	RT/EXT	RI/EXT	FI/EXT	FI/EXT	RI/EXT	RT/EXT	RI/EXT	FI/EXT
1	53.5	44.6	34.9	36.6	52.4	3.6	4.3	4.9	2.3	2.9
2	39.6	31.2	20.1	19.3	35.6	2.0	1.1	1.3	1.4	1.2
3	43.5	35.7	32.8	32.7	51.0	2.5	2.3	3.6	2.5	3.3
$\bar{x}$	45.5	37.1	29.2	29.5	46.3	2.7	2.5	3.2	2.0	2.4
	Bar Presses Per Minute									
1	15.8	38.4	1.8	34.7	31.6	4.3	3.8	.86	4.4	2.9
2	10.5	14.0	.28	17.8	17.5	2.8	2.6	.64	2.1	.88
3	24.7	31.0	9.4	28.8	20.7	8.7	7.1	1.0	4.5	4.6
$\bar{x}$	17.0	27.8	3.8	27.1	23.2	5.2	4.5	.83	3.6	2.7
	Pause Time (sec) Per Pellet									
1	22.9	21.0		17.0	21.5					
2	22.0	14.8		10.1	19.9					
3	21.4	16.8		14.2	20.6					
$\bar{x}$	22.1	17.5		13.7	20.6					

attentuated in every animal by RI and particularly RT schedules, it was not eliminated at any point in the experiment.

Bar Pressing During the Food Component of each Multiple Schedule

All three rats developed bar press rates in Phase 1 that stabilized between 10 and 25 responses per minute. There was some tendency, most dramatic for Rat 1, for rates to increase when the schedule was changed to RI in Phase 2. All three rats showed a large decrease in bar press rates when the RT schedule was imposed in Phase 3. Reintroduction of the RI schedule in Phase 4 produced recovery of bar pressing to rates approximating those observed in Phase 2. There was some tendency for the reinstatement of the FI schedule in Phase 5 to produce a decrease in bar press rates but only Rat 3 showed a rate comparable to that observed in Phase 1.

The main effects of the various phases were assessed statistically by submitting the data shown in Table 1, to a one way ANOVA which indicated a significant overall effect ($\underline{F}(4,8) = 9.09$, $\underline{p} < .05$). A Newman-Keuls test indicated significant differences between Phase 3 (RT) and all other phases. No other comparisons were significant at the .05 level.

Table 1 shows the average post-reinforcement pause times (defined as the time from the delivery of food to the first bar press) during the last eight sessions of the FI/EXT and RI/EXT phases of the experiment. Although post-reinforcement pause times were significantly shorter during the RI/EXT than the FI/EXT phases of the experiment ($\underline{F}(3,6) = 15.7$, $\underline{p} < .05$), pausing after food was by no means eliminated during the RI procedures. As shown in Table 1, the animals maintained pause times of 10.1 sec or greater during the RI phases of the experiment.

Drinking During the Extinction Component of each Multiple Schedule

The right panel of Figure 1 shows drinking and bar pressing during the extinction component for each phase of the experiment. For every rat, drinking occurred very infrequently during the extinction component. Observation of the animals via video monitors revealed that, when drinking did occur during the extinction component, it was nearly always in the first few seconds as part of a bout that began during the food component following a food delivery. Actual initiations of drinking during the extinction component were very rare. The maximum amount of time spent drinking in any extinction period was 10 secs. No systematic relationship can be observed in Figure 1 indicating that significant decreases in food component drinking were accompanied by increases in extinction drinking. A one way ANOVA performed on the data presented in Table 1 revealed no significant overall effect (_F_(4,8) = 1.02, _p_ > .05).

Bar Pressing During the Extinction Component of each Multiple Schedule

Very low rates of bar pressing were observed in all phases of the experiment. ANOVA of the data revealed no significant overall effect (_F_(4,8) = 1.10, _p_ > .05).

Wheel Running in Phase 6

As described earlier when the main experiment depicted in Figure 1 was completed, all 3 rats were given a further series of 20 sessions of FI/EXT training in which a running wheel was substituted for the water bottle, in order to determine if drinking, which Staddon has described as an interim behavior (Staddon, 1977b) and wheel running, which he has also described as an interim behavior (Hinson & Staddon, 1978), have similar patterns of occurrence in FI and Extinction components.

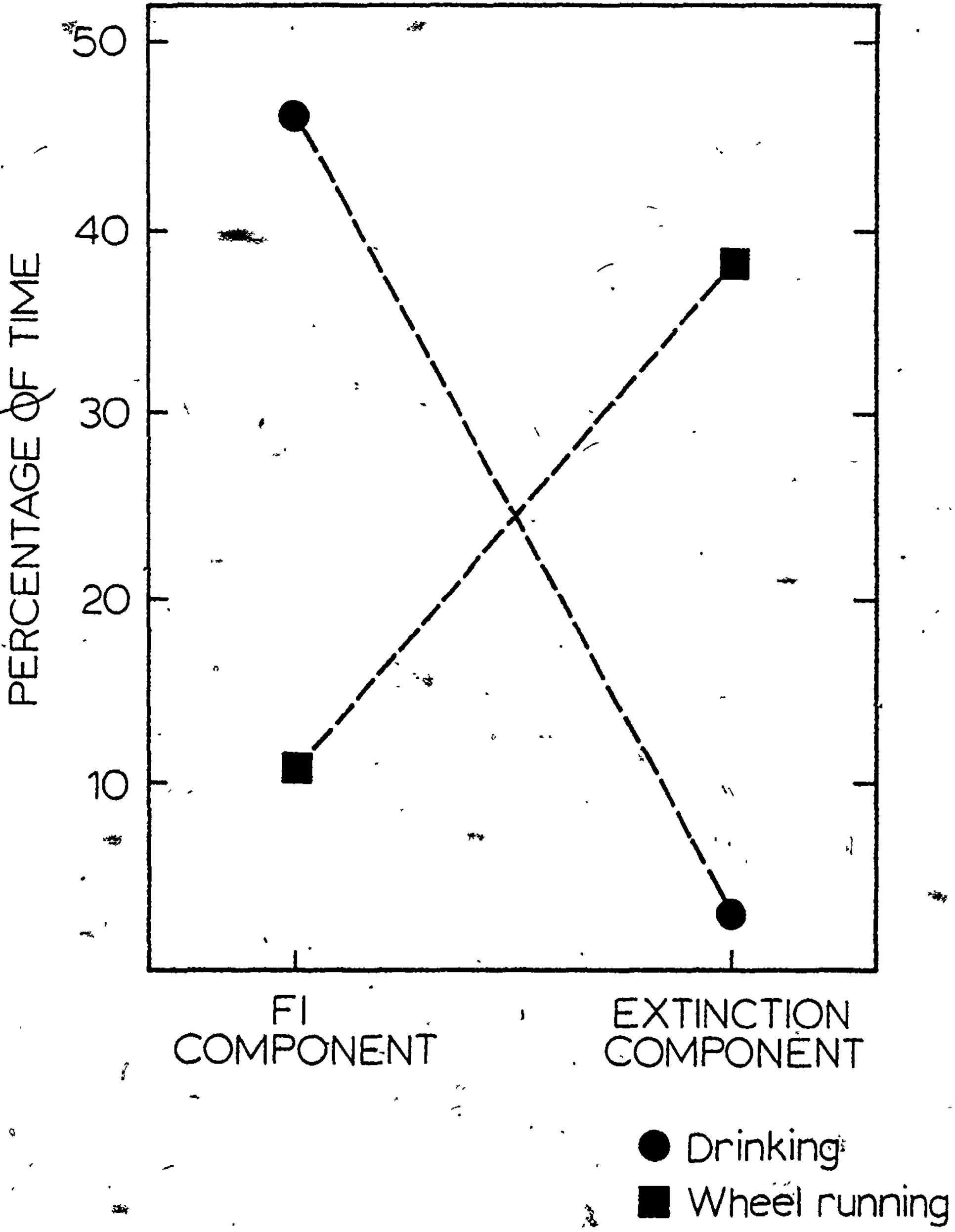
The results of this procedure are presented in Figure 2, which shows the percentage of running time (solid squares) displayed separately for the food and extinction components of the multiple schedule. For comparison, drinking time (circles) during the mult FI/EXT schedule in Phase 5 of the experiment is also presented in Figure 2. Each data point represents performance during the final eight sessions averaged across all three rats. When a water bottle was available, the rats allotted most of their drinking time to the food component of the multiple schedule (Rat 1 = 52.4%; Rat 2 = 35.6%; Rat 3 = 51.0%). Very little drinking occurred in the extinction component (Rat 1 = 2.9%; Rat 2 = 1.2%; Rat 3 = 3.3%). In the wheel only condition, the opposite pattern occurred. A considerable amount of running occurred during the extinction component (Rat 1 = 50.8%; Rat 2 = 31.7%; Rat 3 = 30.8%) whereas relatively little time was spent running in the food component (Rat 1 = 18.0%; Rat 2 = 7.0%; Rat 3 = 9.2%).

Experiment 1a

As described earlier, three additional rats were exposed to a Mult FI/EXT condition for 20 sessions where the flashing light signalled the FI component (counterbalancing stimulus conditions in Experiment 1). Every rat drank very frequently when the FI schedule was in effect. The average percentage of time spent drinking during the last eight sessions was 44.7% for Rat 4, 51.1% for Rat 5 and 41.6% for Rat 6. As in the main experiment, very little drinking occurred during the extinction period (Rat 4 = .89; Rat 5 = .94; Rat 6 = .70). Overall, the data for these three rats were very similar to those obtained in the FI/EXT condition in Experiment 1.

FIGURE 2

Percentage of time spent drinking (solid circles) and wheel running (solid squares) displayed separately for the food and extinction components of Mult FI/EXT schedule. Drinking data represent performance during the final eight sessions of Phase 5; running data, responding during final eight sessions of Phase 6. The data are means across all 3 rats in Experiment 1.


50
40
30
20
10
PERCENTAGE OF TIME
FI COMPONENT
EXTINCTION COMPONENT
● Drinking
■ Wheel running

DISCUSSION

In all phases of the experiment, drinking was almost entirely a post-food activity. Very little drinking occurred during the extinction component of the multiple schedules. Drinking that did occur during extinction was always observed to be a continuation of drinking initiated after presentation of a pellet in the previous food component.

One possible explanation for the lack of drinking in the extinction component is that the stimulus signalling the extinction period (i.e., overhead flashing lights) had some nonassociative effect such that drinking and/or all behavior was suppressed by its presence. This explanation seems unlikely however, since no detrimental effects on drinking were observed in Experiment 1a when the same stimulus signalled the food component of the Mult FI/EXT schedule. Rats in that experiment drank as much or more than the animals in the main experiment. Moreover, when the rats in the main expeirment were given access to a running wheel in Phase 6, they spent a considerable amount of time running during the extinction component signalled by the flashing light. Those results make a nonassociative explanation extremely unlikely.

Polydipsic drinking reliably occurred after food in the FI phases of the experiment. This drinking might be characterized as a S^{-}_{food} activity since food reliably signalled a nonreinforcement period (S^{-} time) on the FI schedule. According to Staddon's S^{-} interpretation of drinking, a second opportunity to drink was available during the extinction component of the FI/EXT schedule. Since this S^{-} period was signalled by a flashing light it can be abbreviated as S^{-}_{light}. The lack of drinking in the extinction component of the FI/EXT schedule might be explained by asserting that food is a valuable and hence extremely salient stimulus for a hungry rat. The light was, in comparison to food, a relatively weak or neutral time marker which induced relatively little drinking. Thus in the FI/EXT phases of the experiment, the S^-_{light} was overshadowed by the S^-_{food}. According to this explanation, drinking should develop during S^-_{light} when RI and RT schedules are in effect since food should no longer be a reliable signal for a S^- period. That result did not occur in this experiment.

There is, however, a possible explanation for the absence of S^-_{light} drinking during RI and RT phases which must be considered before Staddon's account can be seriously questioned. In the present experiment, food was established as a signal for no food in Phase 1 FI training and animals learned to drink in the post-food period. It is possible that this pattern of drinking after eating persisted and interfered with the establishment of a truly random distribution of food deliveries on the RI schedules. An examination of postreinforcement pause, defined as the time from the delivery of food to the first bar press, tends to support this possibility. Although pause time decreased in the RI condition, the animals maintained average pause times of 10.1 sec or greater in the RI conditions. Since the S^-_{food} occasion for drinking was not necessarily eliminated by the RI and RT procedures, drinking in the food component may have overshadowed any drinking that otherwise may have developed in the extinction component. It is obviously necessary to examine the development of drinking in animals exposed to random schedules from the outset of training. That was done in the next experiment.

CHAPTER IV

EXPERIMENT 2

Interim Drinking During Post-Food Times and S^- Times Dissociated From Food

In the first experiment, polydipsic drinking was a food bound activity. Very little drinking occurred during the extinction components of either fixed or random multiple schedules. These preliminary results suggest that drinking is confined to food initiated S^- occasions (S^-_{food}).

Experiment 2 studied four groups of animals each exposed to one of the following reinforcement schedules:

(a) VI 30-sec

(b) RI 30-sec

(c) Mult RI 30-sec/EXT

(d) Mult VI 30-sec/EXT

These experimental groups were chosen so that the following comparisons and questions might be examined. First, this experiment permitted re-examination of the question of whether drinking occurs during S^- periods that are signalled by events other than food. The question of particular interest is whether drinking occurs during Extinction components when a Mult RI/EXT schedule is enforced from the outset of training. Second, an attempt was made to replicate Millenson et al. (1977), by training rats to lever press for food on either VI or RI reinforcement schedules with a water bottle available. As previously mentioned, Millenson et al. found that induced drinking was less reliably obtained on a random interval schedule than on a variable-interval schedule. Lastly, the experiment examined drinking and bar pressing in rats exposed to either simple (VI, RI) or multiple schedules (VI/EXT, RI/EXT) and thus provided an opportunity to replicate an interesting finding by Jacquet (1972) of contrast-like effects with drinking. This effect was observed in transition from a Mult VI/VI to a Mult VI/EXT schedule. Although increase in terminal behaviors such as bar-pressing or key pecking have been observed in many other experiments using similar procedures, Jacquet's finding of behavioral contrast with an interim behavior such as drinking was a relatively novel result.

METHOD

Subjects

The subjects were twenty-eight male hooded rats obtained from the Quebec Breeding Farms. The ad lib weights of the rats were all within a range of ± 5% of 384.7g upon arrival in the laboratory. The rats were reduced to 80% of their free-feeding weights by food deprivation and maintained near those weights for the duration of the experiment. All rats were individually housed with unrestricted access to water.

Apparatus

The experiment was carried out using two chambers housed in separate rooms. Each chamber was identical to that used in Experiment 1. Rats in two groups (VI, RI) were run in one chamber while rats in the remaining groups (VI/EXT, RI/EXT) were run in the other chamber.

Procedure

The rats were randomly assigned to one of four groups of approximately equal mean weight (VI = 306.5 g, RI = 306.2 g, Mult VI/EXT = 308.6 g, Mult RI/EXT = 309.6 g). All animals were trained to lever press for food and then given two sessions of CRF.

The procedures were identical to those of Experiment 1. The values and ordering of the intervals composing the VI 30-sec and Mult VI 30-sec/EXT schedules were as follows: 31, 17, 46, 27, 15, 44, 35.5, 14, 21.5, 51, 40, 18.

Drinking tubes were installed after six initial days of exposure to the experimental conditions. Each group received eighteen daily sessions with the water bottle present.

RESULTS

Table 2 shows the average times for each group to obtain all 60 pellets for the last six sessions in the experiment. There were only minor differences among groups, which suggests that all schedules succeeded in generating reinforcement rates close to the nominal 60 reinforcements/30 minutes for a VI 30-sec schedule and RI 30-sec schedule. The most important implication of Table 2 is that rats on the RI schedule must have received pellets at the programmed random intervals and that the schedule was not contaminated by pausing as in Experiment 1.

Figure 3 shows the average percentage (%) of time spent drinking (left panel) and the average number of barpresses/min (right panel) for each group during Sessions 1-18. The filled circles indicate the group mean for the VI/EXT condition, open circles for the VI-only condition, filled triangles for the RI/EXT condition and open triangles for the RI-only condition. Data from the extinction component of the multiple schedule conditions are displayed separately in the lower panels of Figure 3.

TABLE 2

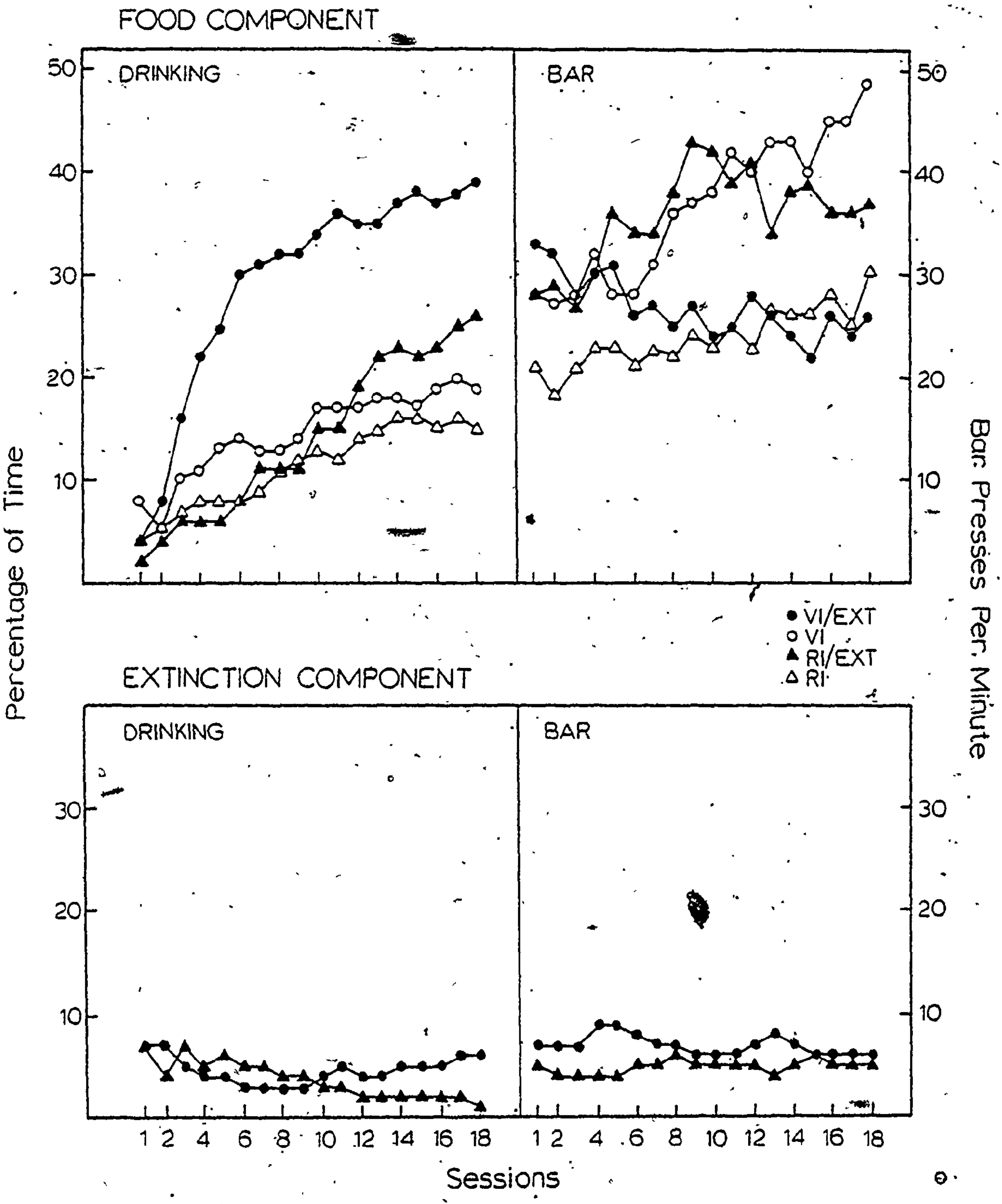
Session Time (in Minutes) for Each Experimental Group

Data are averages of the Last 6 Days

GROUP	TIME	
VI	31.13	
RI	31.17	
Mult VI/EXT	32.18	Food component only
Mult RI/EXT	31.62	Food component only

FIGURE 3

Mean daily rates of barpressing (right panel) and percentage of time spent drinking (left panel) for each experimental group: Mult VI/EXT - solid circles; VI - open circles; Mult RI/EXT - solid triangles; RI - open triangles. Data from the extinction component of the Mult VI/EXT and Mult RI/EXT groups are displayed in the lower panel of Figure 3. Data are means across all seven rats in each experimental group.


FOOD COMPONENT
DRINKING
BAR
EXTINCTION COMPONENT
DRINKING
BAR
Percentage of Time
Bar Presses Per Minute
Sessions
● VI/EXT
○ VI
▲ RI/EXT
△ RI
50
40
30
20
10
1 2 4 6 8 10 12 14 16 18

Inspection of the left panel suggests that the VI/EXT and RI/EXT groups spent more time drinking during the food component than the VI and RI groups. The differences between the VI/EXT and VI-only groups were most noticeable. For example, in the last five sessions, the VI/EXT group spent 37.7% of the food component time drinking compared with an average of 18.6% for the VI-only group. Apparent differences between drinking in the RI/EXT and RI groups developed much later in training. During the last five sessions, the RI/EXT group devoted 23.8% of food component time to drinking compared to 15.5% in the RI-only group. The VI-only group spent more time drinking than the RI-only group throughout the experiment. However, the difference between the groups was small.

Variability within groups was sufficiently great that many of the apparent effects in Figure 3 did not receive statistical confirmation. The drinking data in Figure 3 were submitted to a 2(Extinction vs. no extinction) X 2(VI vs. RI) X 18(sessions) analysis of variance. This analysis indicated that, although inspection of Figure 3 suggests that higher levels of drinking were produced by the RI/EXT and VI/EXT than the RI and VI schedules, neither the main effect of Extinction nor the EXT X Session interaction was significant (Extinction: $\underline{F}(1,24) = 2.99$, $\underline{p} = .096$; EXT X Sessions: $\underline{F}(17,408) = .849$, $\underline{p} = .634$). There was also no significant main effect of VI vs. RI schedules ($\underline{F}(1,24) = 2.16$, $\underline{p} = .153$), but there was a significant Schedules X Session interaction ($\underline{F}(17,408) = 2.24$, $\underline{p} = .003$), indicating that there were only minor differences attributable to the VI vs. RI variables in early sessions but greater differences in later sessions. Finally, there was a significant main effect of Sessions ($\underline{F}(17,408) = 2.33$, $\underline{p} = .002$) reflecting a general tendency in all groups for drinking to increase as training continued.

Barpresses/min are presented for each group throughout the experiment in the right panel of Figure 3. Prior to Sessions 1-18, the animals had been exposed to six sessions without a water bottle available. The group means calculated for these initial six days were as follows: VI/EXT = 28.6, RI/EXT = 21.7, VI = 20.6, and RI = 16.7. As shown in Figure 3, differences developed among the groups as training progressed, with the RI/EXT and VI-only groups barpressing at levels above the VI/EXT and RI groups. During the last six days of training, barpresses/min averaged 44.1 for the VI-only group and 36.8 for the RI/EXT group. Barpressing rates for the RI and VI/EXT groups were 27.1 and 25.0. Again however, there was considerable variability and overlap among groups in rates of barpressing and a 2(EXT vs. no EXT) X 2(VI vs. RI) X 18(Sess) ANOVA revealed no significant main effects, and no significant interactions.

Extinction component

The percentage of time spent drinking during the extinction component of each multiple schedule is presented in the lower right panel of Figure 3. The total drinking time never exceeded 2 minutes for either group. There was, in fact, some tendency for drinking in S^- to decrease as training progressed, an effect that was reflected in the ANOVA by a significant Sessions effect ($F(17,204) = 3.53$, $p < .01$). Note also that the VI/EXT rats drank slightly less than RI/EXT rats in early sessions, but slightly more in later sessions. That effect was reflected in a significant Schedule X Session interaction ($F(17,204) = 2.19$, $p < .01$).

Observation of animals indicated that drinking during the extinction component after the initial days of training was confined to the early seconds of each extinction period. As in Experiment 1, S^- drinking was typically initiated by the delivery of a food pellet in the preceding food component.

Barpressing (lower right panel) occurred at relatively low levels during the extinction component of each multiple schedule. ANOVA revealed no significant schedule effects and no significant interaction.

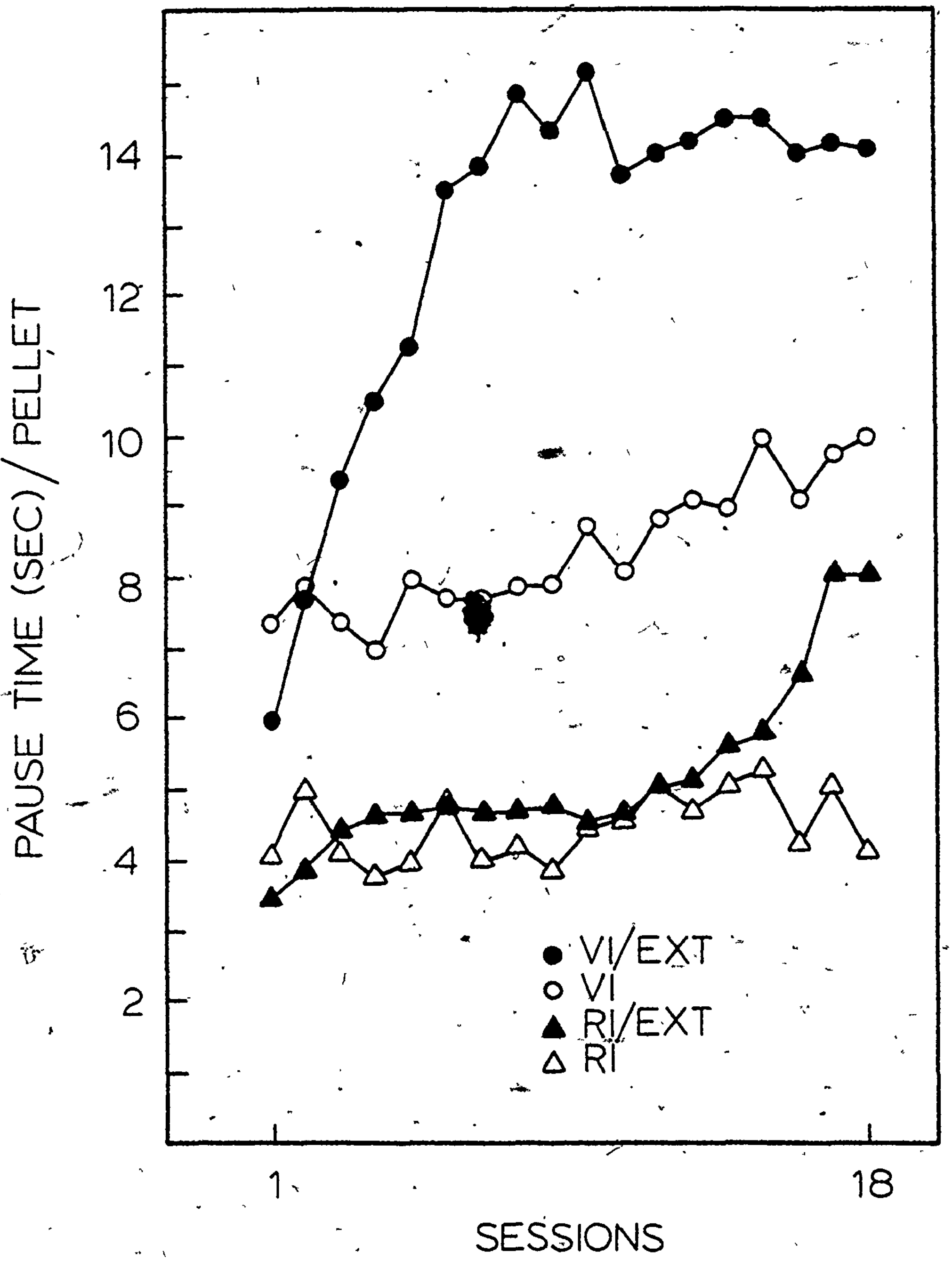
Figure 4 shows average post-reinforcement pause time for each group across the 18 days of the experiment when a water bottle was available. For the RI-only group, the duration of post-reinforcement pauses was short, ranging between 3.8 sec and 5.4 sec. A substantial portion of this time was spent consuming the food pellet. Pause-time in the RI/EXT group ranged from 3.5 secs to [illegible].1 secs in the initial 12 days of training and increased to a maximum of 8.1 secs in later sessions. Longer pause times occurred in the VI-only group and especially the VI/EXT group. Pause duration in the latter group ranged from 6.0 sec to 15.2 sec. These effects were all confirmed in an ANOVA, which detected significant main effects of Extinction ($\underline{F}(1,24) = 4.97$, $\underline{p} < .05$), Schedule ($\underline{F}(1,24) = 12.4$, $\underline{p} < .01$) and a significant Extinction X Schedule X Sessions interaction ($\underline{F}(17,408) = 1.68$, $\underline{p} < .05$).

DISCUSSION

The main findings of Experiment 2 were: (1) that RI and VI schedules induced different levels of drinking; (2) there was a noticeable, but nonsignificant, tendency for drinking to increase in both RI

Figure 4

Mean daily pause time (sec) per pellet for all four experimental groups. Data are means across seven animals in each group.


PAUSE TIME (SEC)/PELLET
2
4
6
8
10
12
14
SESSIONS
1
18
● VI/EXT
○ VI
▲ RI/EXT
△ RI

and VI components when they alternated with extinction periods; and (3) drinking did not occur with any appreciable frequency during S^- periods.

Previous research suggests that drinking is less reliably obtained on RI schedules. In an experiment conducted by Millenson et al. (1977), six of the eight rats exposed to a RI schedule failed to develop polydipsia whereas all four rats on a VI schedule drank excessively. For the two exceptions in Millenson's RI group, drinking increased over training and ultimately reached levels similar to those obtained by VI rats. Drinking in these animals was also similar to VI drinking in that it occurred immediately after pellet delivery. A similar result occurred in this experiment. One rat in each of Group RI and RI/EXT began drinking when the water bottle was introduced and this post-pellet drinking continued to increase throughout the experiment. In these cases, the animal's initial behavior alters the properties of the schedule. By drinking after eating, the animal changes the distribution of interpellet intervals so that the RI schedule more closely resembles a VI. According to Staddon (1977b) this kind of schedule - behavior interaction is not an uncommon occurrence in situations that allow induced behavior. The results of this experiment and those of Experiment 1 suggest that this type of interaction is especially likely to interfere with the assessment and interpretation of drinking on RI schedules of reinforcement.

There was a tendency for drinking to increase in the VI component when it alternated with extinction periods. A similar but smaller effect appeared to develop much later in training in the RI/EXT group. This effect was not statistically reliable, however, because neither the main effect of EXT nor the Session X EXT interaction was significant. It should be noted, however, that this experiment was terminated at a time when both VI/EXT and RI/EXT groups were still showing increasing levels of drinking and it is possible that further training would have produced more dramatic effects of the extinction component. At present, we can only note that there was some support for Jacquet's (1972) finding that an extinction component facilitates drinking, but that the effect was inconsistent and not statistically significant. It is probably important to note that this experiment also failed to demonstrate a contrast effect in barpressing, a widely-recognized robust phenomenon. Perhaps the difficulty stems from the between-groups design used in Experiment 2, because most demonstrations of contrast have used a within-subject design in which, for example, animals are trained initially on a VI schedule, then switched to VI/EXT to assess possible facilitating effects of the extinction component, then returned to VI. Jacquet's (1972) finding obviously deserves replication with such a design. Further data pertaining to this question are reported in Experiment 3.

The far more important finding, however, is that drinking did not occur as a S^- activity even when the RI component was enforced from the outset of training. This clearly argues against Staddon's S^- account of interim drinking.

CHAPTER V

EXPERIMENT 3

Interactive Effects of Drinking and Running During Post-Food S^- Times and S^- Times Dissociated from Food

Recently, Staddon (1977b) has criticized the traditional single component approach to the study of operant behavior. He has argued for a more molar view which involves the study of interactions among a variety of behaviors. According to Staddon, "The 'laws' of operant behavior are not a property of isolated reflexes, but emergent properties of a set of interactions among induced states and their associated behaviors" (Staddon, 1977b, p. 148).

If one seriously considers Staddon's multi-component approach to operant behavior, then interim and terminal behavior cannot be productively studied in isolation. Although the experiments reported previously in this thesis were mainly concerned with interim drinking, it may well be that the level and distribution of interim drinking can only be understood in relation to other behaviors that interact and compete for available time on periodic food schedules. Can Staddon's multi-component approach be applied to performance in Experiments 1 & 2?

In recent writings, Staddon has increasingly emphasized the idea of competition as an important factor in determining the level and distribution of any one behavior in an animal's repertoire. Staddon's analysis of performance is based on the view that "organisms optimize not a single variable, such as reinforcement rate, but rather some function of the total repertoire of behavior, subject to limitations of time and the constraints imposed by the schedule" (Staddon, 1979, p. 50).

The allocation of time to any given response is determined by the competitive relationships among all behaviors in the animal's total repertoire. For example, when a hungry rat is given food on a periodic schedule, a proportion of each inter-food interval may be taken up by the terminal response, another portion by induced interim behavior such as drinking and a third portion may be devoted to other facultative activities, such as wheel running.

One of the major assumptions of the time allocation model is that in the steady state, any change in the rate of one activity will produce a complementary change in the level of others. The model predicts that if drinking, for example, is prevented, other activities in the animal's repertoire such as barpressing and running should expand to occupy the time made available. Although only a few studies provide relevant information, there is some evidence that when interim drinking is prevented, increases in the level of other activities do occur (Cook & Singer, 1976; Iversen, 1977; Staddon & Ayres, 1975). In the experiment by Cook and Singer (1976) food deprived rats drank excessively after eating on a FI 60-sec schedule. When the drinking tube was empty, licking decreased and large increases occurred in all other activities such as barpressing, exploratory behaviors and grooming. When the filled drinking tube was reinstated, all behaviors returned to their original levels.

Although it is difficult to specify the exact nature of the relationship between interim and terminal behavior in the experiments previously reported in this thesis, an analysis of performance based on competition leads to some interesting hypotheses concerning (a) the allocation of drinking in the food and extinction components of the multiple schedules and (b) the level of interim drinking and barpressing within the food component of the multiple schedule.

Allocation of Drinking in the Food and Extinction Components of the Multiple Schedules

If interim and terminal activities, as Staddon (1977b) suggests, are antagonistic classes of behavior which interact and compete for available time, the reallocation of drinking from the food component of the multiple schedule to the extinction component might have been most likely to occur in the RI/EXT condition of Experiment 2. In this condition, barpressing increased in the food component from an average rate of 21.7 responses/min before water was available to 36.8 responses/min in the final six days of training when water was available. The time allocation model predicts that the change in the rate of barpressing should produce a complementary change in the level of other activities, so it is reasonable to suggest that less time will be available for other activities such as drinking when barpressing occupies a greater amount of the inter-food interval. According to Staddon, a second opportunity to engage in interim activity is provided by the extinction component of the schedule. Terminal responding occurs at a relatively lower rate in this component and since this source of suppression is removed, drinking should be free to occupy a large percentage of time within the extinction component of the multiple schedule. However, in Experiment 2, the reallocation of drinking to the extinction component did not occur as expected from Staddon's account. These results are inconsistent with observations by Hinson and Staddon (1978) in which running was reallocated to the extinction component of a multiple VI/EXT schedule.

It is also interesting that in Experiment 1, drinking and running were allocated to different components of the multiple schedule. Rats trained on a FI/EXT schedule allotted most of their drinking time to the food component when a water bottle was available whereas running occurred primarily during the extinction component, when a running wheel was available. These results suggest that drinking and wheel running differ in the extent to which they can be reallocated to S^- times dissociated from food. This difference may account for the discrepancy between the present experiments and Hinson and Staddon's data.

Level of Interim and Terminal Activities within the Food Component of the Multiple Schedules

In both Experiments 1 and 2 drinking and barpressing were confined to the food component of the multiple schedules. These interim and terminal activities, according to Staddon, compete for the time available on the food schedule. A variety of outcomes might be anticipated when these food-bound interim and terminal activities compete for the time available: (a) increases in interim activities may occur at the expense of terminal responding; (b) terminal responses may increase while interim activities decrease; or (c) both interim and terminal responses may increase.

The results of Experiments 1 and 2 suggest that it may be difficult to predict the outcome of the competition between interim and terminal responses in any given experimental setting. In some instances, interim activity may increase at the expense of terminal responses. For example, there was a slight tendency for barpressing to decrease in the VI/EXT condition of Experiment 2 when drinking increased. Although this effect was small, it might have become larger with further training. A more typical observation is that increases in terminal responding occur at the expense of interim activities (behavior contrast). However, in most experimental settings, little stimulus support is provided for inducing strongly competing interim activities so this "contrast" result may not be as general as is popularly supposed. A third possibility is that both interim and terminal activities increase in strength, as observed in the Jacquet (1972) experiment. At first, this alternative appears inconsistent with the major assumption of the time allocation model since it requires that an increase in the rate of one activity will be associated with a decrease in others. However, this outcome can be accommodated within the model, if behavior in a third response category is considered in the analysis of performance. For example, in Experiment 2, it is possible that "othe[illegible]recorded activities as well as interim and terminal responses competed for time available. Indeed, the level and distribution of both barpressing and drinking may have depended on the strength of behavior in this "other" category. In an experiment by Staddon and Ayres (1975) the proportion of the interval devoted to barpressing and drinking was dependent upon the strength of the facultative behavior of wheel running. It is not known what role, if any, behavior in this facultative category played in the results of the first two experiments. In these experiments, no attempt was made to measure facultative behavior in order to determine its influence on the level and distribution of interim and terminal responding.

Experiment 3 attempted to assess the interactive effects of these three classes of behavior (<u>viz.</u>, interim, facultative and terminal) by exposing animals to VI and VI/EXT schedules in a situation where drinking, wheel running and barpressing activities were simultaneously available.

The purpose of the experiment was to: (1) replicate the major findings of Experiments 1 and 2 that drinking is a food-bound activity that does not occur in S^- periods signalled by stimuli other than food, (2) determine if running is similarly a food-bound activity or if it occurs in S^- periods signalled by stimuli other than food (e.g., Hinson & Staddon, 1978), and (3) determine if competition among these three major response classes enables one to account for changes in the allocation of time to any given response produced by the multiple schedule procedure.

METHOD

Subjects

Ten adult male hooded rats obtained from Quebec Breeding Farms were used in the experiment. Prior to the beginning of the experiment the rats were reduced to 80% of their *ad lib* weight and maintained at those weights throughout the experiment.

Apparatus

The apparatus was the same as that used in Experiment 2 in the VI/EXT condition.

Procedure

Pretraining. Two days prior to the beginning of the experiment, each rat was allowed to run for 20 min per day in a wheel similar to the one attached to the operant chamber. All rats learned to run and the number of revolutions per 20 min averaged about 150 on Day 2.

The rats were magazine trained and shaped to lever press in the operant chamber. In the next two sessions, a lever pressing response resulted in delivery of a food pellet. Each session terminated after delivery of the fortieth pellet.

Experimental sessions. The rats were randomly assigned to one of two groups of approximately equal mean weight (Group 1 = 293.8 g, Group 2 = 291.4 g). For Group 1 the following experimental conditions were imposed: Condition 1, VI 30-sec schedule for food reinforcement; Condition 2, multiple VI 30/EXT schedule; Condition 3, VI 30-sec schedule. For Group 2, the sequence was: Condition 1, multiple VI 30/EXT schedule of food reinforcement; Condition 2, VI 30-sec schedule; Condition 3, multiple VI 30/EXT schedule. Each VI-only and VI/EXT session was conducted in the manner of Experiment 2. Condition 1 for both groups was preceded by six days of exposure to the reinforcement schedule with the water bottle removed and access to the wheel blocked. Thereafter, animals received 20 sessions in Conditions 1 and 3 and 30 sessions in Condition 2 of the experiment. The water bottle and wheel were freely accessible throughout all these sessions except during Sessions 3 and 4 in Condition 1 when the wheel was blocked to permit the development of drinking. Each session concluded when 40 pellets had been collected.

In addition to the measures described previously in Experiments 1 and 2, time spent pressing the lever was recorded by a clock which started when the Microswitch on the lever was closed (lever depressed) and stopped when the Microswitch opened. Feeder time was recorded by a clock which started when the Microswitch on the feeder door was closed (door opened) and stopped when the door closed (Microswitch opened).

Percentage of time was used as the dependent measure of all behavior (i.e., drinking, wheel running, bar and feeder activities) in this experiment. This method of measurement focuses attention on how session time is allocated. The argument in favor of time rather than number of responses as a fundamental measure has been made by many researchers (e.g., Premack, 1965) and is of fundamental importance to recently proposed time allocation models (Rachlin & Burkhard, 1978).

RESULTS

The results of the experiment are presented for Group 1 in Figure 5 and for Group 2 in Figure 6.

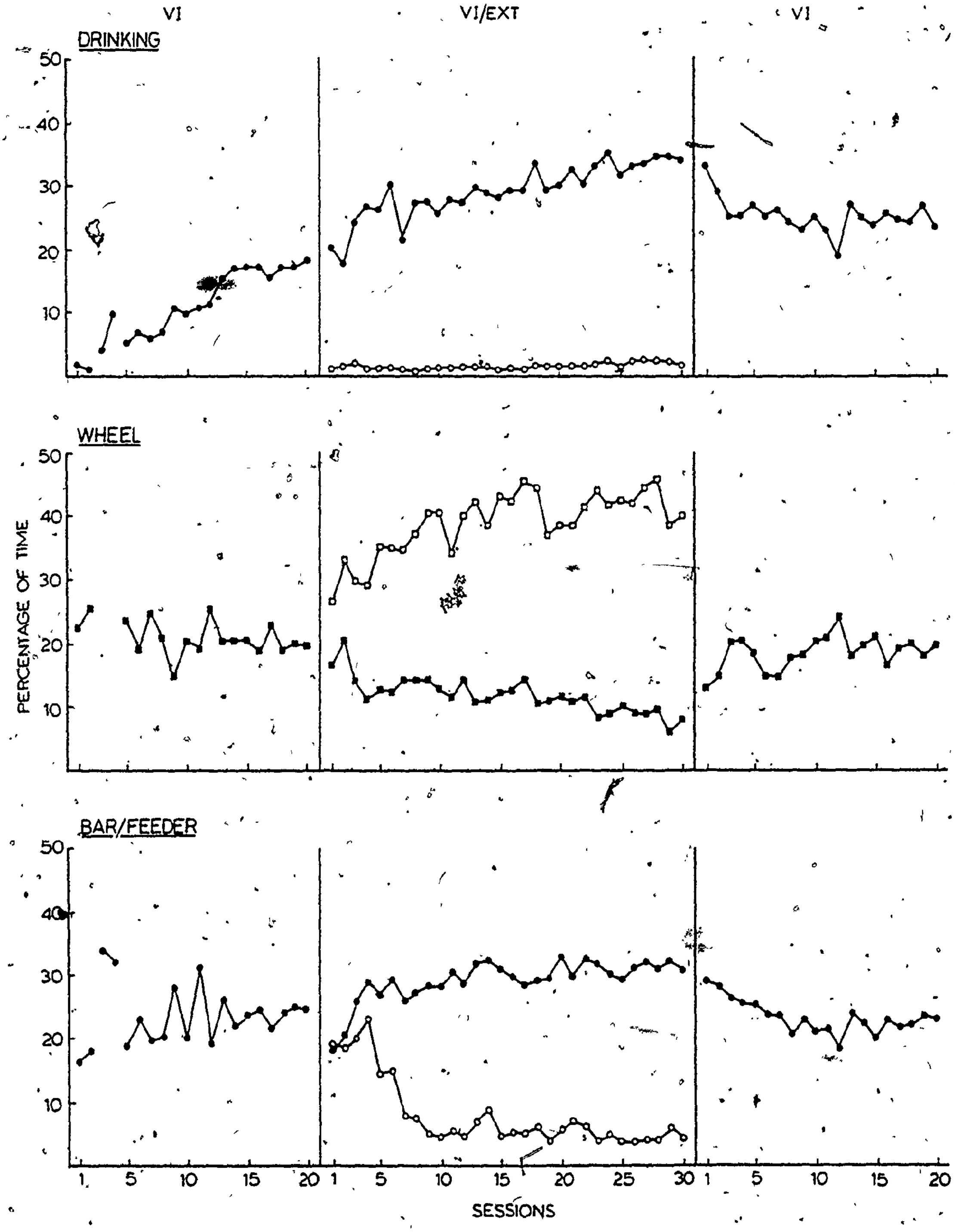
Group 1

Figure 5 shows the percentage of time devoted to drinking, wheel running, bar and feeder activities as a function of sessions across each of the three conditions. Each point represents a group mean based on all five rats in Group 1. In this figure, the filled symbols indicate activity during the VI schedule and the open symbols indicate activity during the extinction component when the multiple schedule was in effect. Since barpressing and feeder activities are both behaviors which occur in anticipation of food, they were combined to provide a more complete measure of terminal responding.

Drinking. Drinking (top panel) gradually increased across sessions in the initial VI-only condition and stabilized so that in the last five sessions, the rats drank an average of 17.1% of the time. In Condition 2, when the VI component alternated with extinction periods, the percentage of time devoted to drinking increased. In the last five sessions of the Mult VI/EXT condition, the average percentage of drinking time was 34.0 (almost double that observed in the VI-only condition).

FIGURE 5

Mean daily percentages of time devoted to drinking, wheel running and bar/feeder across each of the three experimental conditions for Group 1: VI-only; Mult VI/EXT; VI-only. Filled symbols indicate activity during VI schedule; open symbols, activity during the extinction component in the mult VI/EXT condition. Each data point represents a group mean based on all five rats. Access to the wheel was blocked in sessions 3 and 4.


VI
VI/EXT
VI
DRINKING
WHEEL
BAR/FEEDER
PERCENTAGE OF TIME
50
40
30
20
10
1
5
10
15
20
25
30
SESSIONS

Relatively little drinking occurred during the extinction component of the multiple schedule (open circles). In condition 3, when the animals were returned to VI-only there was a marked decrease in drinking following food. However, the mean level of drinking in the last five days remained slightly above that observed in the initial VI-only condition.

Running. The percentage of time devoted to running (middle panel, solid squares) fluctuated across sessions in the initial VI-only condition and eventually stabilized so that the rats devoted an average of 20.2% of the VI time to wheel running during the final five sessions. When the schedule was changed to VI/EXT, wheel running during the food component decreased to 8.4% in the last five sessions. Wheel running occurred far more frequently in the extinction (open squares) than in the VI component of the multiple schedule.. The average percentage of time devoted to running in extinction for Group 1 was 42.2%. When the animals were returned to the VI-only schedule, running returned to levels (18.7%) observed in condition 1.

Bar and Feeder. The time devoted to these activities varied across the initial VI-only condition. An average of 23.9% of time was spent engaged in bar/feeder activities in the last five sessions. When access to the wheel was blocked in sessions 3 and 4, substantial increases in bar and feeder activities were observed. In condition 2, bar/feeder activity during the food component of the multiple schedule was somewhat suppressed in the initial session but, it gradually recovered in the remaining sessions to a level (31.5%) greater than that observed in the last five sessions of condition 1 (23.9%). Although a considerable amount of bar/feeder activity was observed during the extinction component in early sessions, it gradually declined to relatively low levels in later sessions. When the animals were returned to VI-only, bar/feeder activity decreased and in the last five sessions, rats devoted 22.7% of the session to bar/feeder activity.

In summary, for Group 1, the Mult VI/EXT condition produced increases in drinking during the food component (an average increase of approximately 49.7%) and slightly smaller increases in bar/feeder activities (an average increase of approximately 34.9%). There were substantial decreases in wheel running during the food component (an average decrease of approximately 58.4%). More time was spent wheel running in the extinction than in the food component of the multiple schedule.

Table 3 shows drinking, running and bar/feeder activity for individual rats averaged across the last five sessions of each condition. Inspecting the data for Group 1 indicates that the effects summarized for each activity in Figure 3 occurred in practically every rat. The exception was Rat 5 who showed levels of food component running in condition 2 that were lower than in condition 3 but not condition 1. For rats 2, 3 and 4 increases in bar/feeder activity in the VI/EXT condition occurred only in comparison with the final VI-only condition.

Group 2

The results for Group 2 are presented in Figure 6. As in Figure 5, the filled symbols indicate activity during the VI schedule and the open symbols indicate activity during the extinction component when the multiple schedule was in effect. The pattern of results was somewhat more complex for these animals who were initially exposed to the VI/EXT condition.

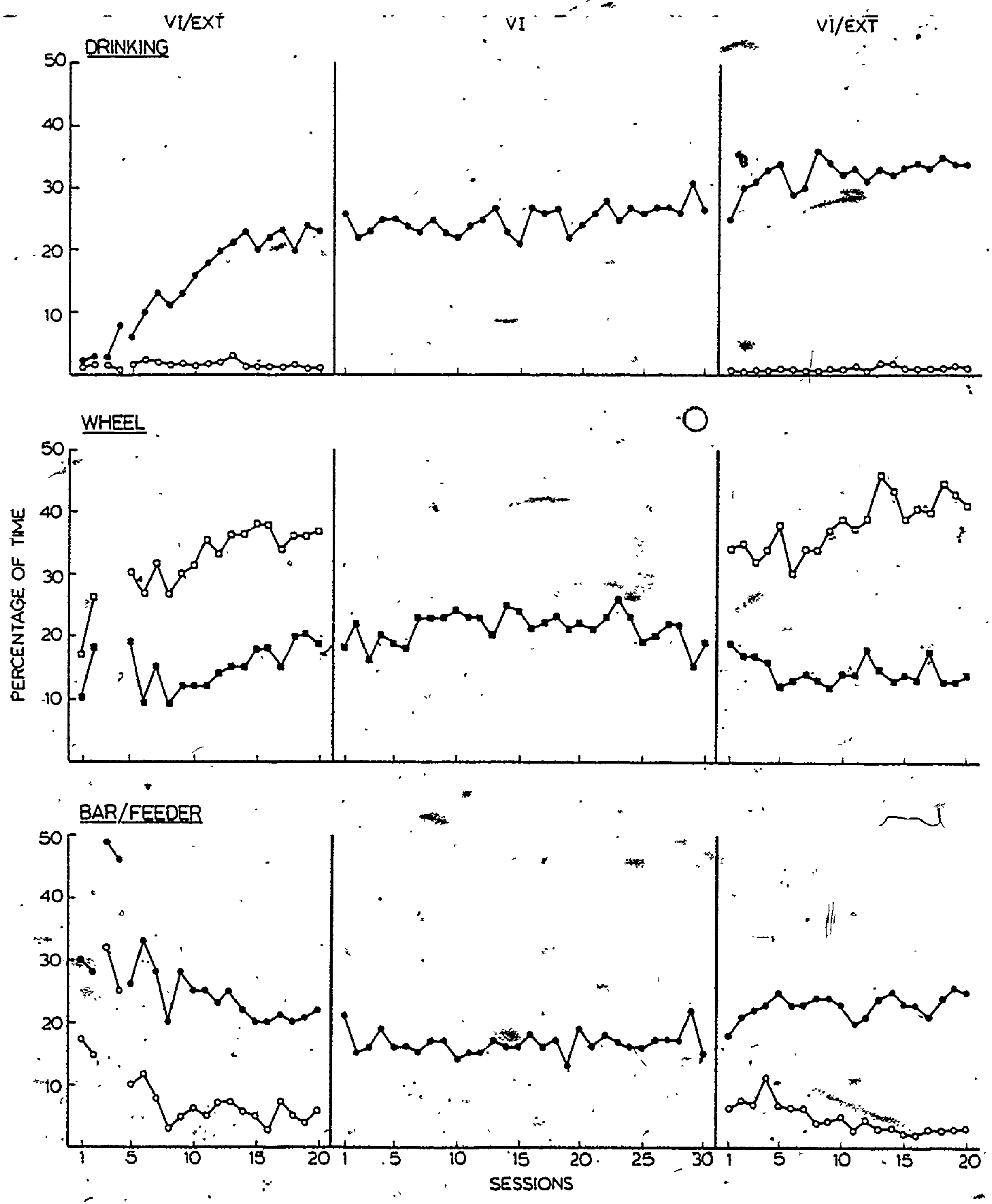
TABLE 3

Percentage of Time Devoted to Drinking, Running and Bar/Feeder for Individual Rats in Groups 1 and 2. Data are Means over the Last Five Sessions of Each Condition

GROUP 1					GROUP 2					
DRINKING					DRINKING					
Rat	VI	VI/EXT		VI	Rat	VI/EXT		VI	VI/EXT	
1	5.6	18.0	.88	11.7	6	25.2	.25	28.4	29.1	.25
2	33.2	46.0	5.7	23.1	7	7.3	2.6	33.2	54.0	4.0
3	6.4	42.6	2.3	34.6	8	39.2	2.4	36.8	46.5	1.2
4	29.0	43.7	2.6	39.6	9	5.9	.38	7.3	7.0	.03
5	11.5	20.1	.09	16.6	10	34.6	1.1	31.0	34.0	.38
$\bar{x}$	17.1	34.0	2.3	25.1	$\bar{x}$	22.4	1.3	27.3	34.1	1.1
RUNNING					RUNNING					
1	35.8	15.0	53.6	25.9	6	30.9	51.6	24.1	26.2	57.8
2	9.4	3.1	37.2	24.9	7	6.7	19.1	5.4	.93	16.5
3	18.6	.21	15.8	4.1	8	1.3	25.6	9.3	1.3	38.5
4	17.0	2.4	49.3	14.3	9	41.8	53.9	40.5	28.4	59.2
5	20.2	21.3	55.1	24.6	10	9.6	31.6	19.1	13.7	39.7
$\bar{x}$	20.2	8.4	42.2	18.7	$\bar{x}$	18.0	36.3	19.6	14.1	42.3
BAR/FEEDER					BAR/FEEDER					
1	11.1	25.3	1.2	16.3	6	13.6	.64	14.7	19[illegible]	.59
2	28.8	29.6	2.4	15.9	7	25.1	3.3	20.9	22.3	5.9
3	32.5	34.4	2.2	28.0	8	31.5	6.4	20.3	28.8	3.9
4	34.1	38.1	6.1	28.9	9	12.6	2.3	16.3	28.2	1.2
5	13.2	30.2	3.7	24.4	10	21.0	3.4	16.3	19.9	1.0
$\bar{x}$	23.9	31.5	3.1	22.7	$\bar{x}$	20.7	3.2	17.7	23.8	2.5

FIGURE 6

Mean daily percentages of time devoted to drinking, wheel running and bar/feeder across each of the three experimental conditions for Group 2: Mult VI/EXT; VI-only; Mult VI/EXT. Other details as for Figure 5.


VI/EXT
VI
VI/EXT
DRINKING
50
40
30
20
10
WHEEL
50
40
30
20
10
PERCENTAGE OF TIME
BAR/FEEDER
50
40
30
20
10
1
5
10
15
20
1
5
10
15
20
25
30
1
5
10
15
20
SESSIONS

Drinking. As shown in Figure 6 there was a slight tendency for drinking to increase across the three conditions. The average percentage of time spent drinking in the last five days of each condition was: VI/EXT = 22.4%; VI-only = 27.3%; and VI/EXT = 34.1%. The right panel of Table 3 shows that the direction of these changes across conditions was representative of the performance of three rats (Rats 6, 7, 9). For Rats 8 and 10, drinking decreased slightly when the schedule was changed from VI/EXT to VI-only and increased when the VI/EXT conditions were reinstated. As in Group 1, relatively little time was spent drinking during the extinction component of the multiple schedule in either condition 1 or 3.

Running. As shown in Figure 6, running during the food component (solid squares) increased gradually in the initial VI/EXT condition. There is some suggestion of a pattern of increased running in condition 2 when the schedule was changed to VI-only, and a decline in condition 3 running when the schedule was changed back to Mult VI/EXT. Table 3 indicates, however, that this pattern was evident in only Rats 8 and 10.

Running occurred more frequently in the extinction than in the food component of each multiple schedule condition. The average percentage of time devoted to running in extinction was 36.3% for condition 1 and 42.3% for condition 3.

Bar and Feeder. As in Group 1, substantial increases in bar/feeder activities were observed in sessions 3 and 4 when access to the wheel was blocked. As indicated in Figure 6, bar/feeder activity (solid circles) declined gradually across sessions in the initial VI/EXT condition eventually stabilizing with a mean of 20.7% in the last five sessions. In condition 2, when the schedule was changed to VI-only, bar/feeder activities declined slightly and then increased when the VI/EXT conditions were reinstated in condition 3. The performances of Rats 7, 8 and 10 were consistent with this pattern. For Rats 6 and 9, bar/feeder activity tended to increase across all three conditions.

Bar/feeder activity during extinction, in both conditions 1 and 3, declined across sessions and occurred relatively infrequently when compared to levels observed in the food component of the multiple schedule.

DISCUSSION

In the present experiment, one group of animals was exposed to a prototypical contrast paradigm (VI → VI/EXT → VI). When reinforcement was delivered on a VI schedule, the animals devoted a portion of time within the interfood interval to drinking, wheel running, and to bar/feeder activities. When the VI schedule alternated with extinction periods in the next condition of the experiment, increases were observed in the percentage of time devoted to drinking and terminal activities of bar and feeder (positive behavioral contrast). Running occurred at high levels during the extinction period and decreased in the food component of the multiple schedule. The drinking contrast effect was consistent across all rats and if anything slightly stronger than the bar/feeder contrast effect. These results support the response-competition hypothesis offered by Staddon (1977a; Hinson & Staddon, 1978). The decrease in running in the VI component and high levels during extinction periods indicate that the animals reallocated this facultative behavior in the way predicted by the response competition hypothesis. If one assumes that running suppressed both drinking and terminal activities in the VI schedule, the enhancement of both drinking and bar-feeder by a Mult VI/EXT schedule can be explained by disinhibition owing to the shift of competing activity (i.e., running) away from the S^+ into the S^- component as described by Hinson and Staddon (1978). The remaining food-bound interim and terminal activities were both free to increase, leading to a intermediate or modest contrast effect in both as they competed for the time made available by the shift of wheel running behavior. It is important to emphasize, however, that drinking again emerged as a food-bound activity. This property of drinking may have been responsible for the lack of a robust barpress contrast effect. In a Mult VI/EXT schedule where barpressing and drinking are both possible, those activities will presumably compete in the food component of the schedule which would tend to limit the occurrence of barpressing. A much larger contrast effect might be observed in situations in which there is no competing food-bound behavior as in the Hinson and Staddon (1978) experiment.

The results for the animals exposed to the Mult VI/EXT schedule from the outset of training were slightly more complicated. A similar symmetrical account based on the response competition hypothesis predicts that drinking and terminal activities should decline as wheel running increases, when the schedule is changed from VI/EXT to VI-only. When VI/EXT is reinstated, drinking and barpressing should increase as running decreases in the food component of the schedule. This pattern of results was only evident in two of the five animals in the group (Rats 8 & 10). The explanation for these smaller and less reliably produced effects when VI/EXT was enforced from the outset of training is not clear. However, there is some indication in the literature that such results could be expected. In an experiment using pigeons, Kodera and Rilling (1976) examined the effects of the amount of prior nondifferential exposure to the positive stimulus on the magnitude of behavioral contrast (i.e., increases in terminal responding). The positive stimulus (S^+) was a green keylight associated with a VI 30-sec schedule of reinforcement. In discrimination training the keylight alternated with a 60-sec period of extinction when the key was dark (S^-) and no food was delivered. Kodera and Rilling found a significantly larger contrast effect when pigeons were initially exposed to the S^+ followed by discrimination training than when discrimination training was initiated with no prior exposure to the S^+ alone.

With respect to interim behavior, Reberg (1980) found that, when established early in training, post-food drinking was a very strong behavior that was extremely difficult to eliminate. This is consistent with the finding that drinking established in condition 1 of Mult VI/EXT training did not decrease when the schedule was subsequently changed to VI-only in condition 2. It is not clear whether the competition hypothesis can account for the difficulties in obtaining contrast effects in the VI/EXT → VI → VI/EXT procedure used in Group 2.

CHAPTER VI

General Discussion

The results of these experiments indicate that drinking is a food-bound activity that does not occur in S^- periods signalled by stimuli other than food. Drinking, in the present experiments, might be characterized as a S^-_{food} activity since drinking reliably occurred during occasions when food signalled a nonreinforcement period. Very little drinking occurred during S^-_{light} occasions. The results of these experiments also suggest that while drinking might be characterized as S^-_{food} activity, running occurs in S^- periods signalled by stimuli other than food. The remainder of this discussion focuses on the relationship between eating and drinking, the differences between drinking and wheel running, and the implication of these results for Staddon's time allocation model of contrast.

The Relationship between Eating and Drinking

Staddon (1977b) suggests that drinking is representative of a class of behavior which occurs at times, or in the presence of stimuli, that signal the absence of food (S^- or interim periods). In conjunction with stressing the importance of S^- periods for the induction of interim drinking, Staddon's account clearly implies that drinking, like other interim behavior, should occur in S^- periods that are signalled by events other than food.

The experiments reported in this thesis examined Staddon's S^- interpretation of interim behavior by studying drinking in different schedules of positive reinforcement. If interim drinking results from a negative contingency that prevails when a stimulus signals a period in which food never occurs, multiple schedules in which reinforcement is delivered on either a fixed or variable schedule alternated with periods of extinction should provide, according to Staddon's account, two occasions for drinking: a food → no food contingency (S^{-}_{food}) where food deliveries signal a period in which food never occurs, and a light → no food contingency where light or some other stimulus signals the unavailability of food in the extinction component of the multiple schedule.

The results of the present experiment offer no indication that drinking occurs during S^{-} occasions that are dissociated from food. Drinking, in the present experiments, was confined to the food component of each multiple schedule with very little drinking occurring during the extinction component (S^{-}_{light}). Most of the drinking that did occur during extinction periods consisted of a spill-over from drinking initiated after eating a pellet delivered in the previous food component. Furthermore, drinking was not reallocated to S^{-}_{light} times under circumstances where increases in terminal responding may have interfered with drinking after presentation of a pellet in the food component of the multiple schedule.

Other experiments in which a stimulus other than food bears a similar predictive relation to food delivery such as those employing second-order schedules (e.g., Allen, Porter & Arazie, 1975) have also reported less post-stimulus drinking following a nonfood stimulus.

Explanations to account for these data within the framework of Staddon's account have not been totally convincing. For example, it has been suggested that the failure to drink after a nonfood stimulus is attributable to the poorer (temporal) discriminative control exerted by nonfood stimuli (Reid & Staddon, 1981 in preparation). According to this account, weak temporal control results in a reduction of the post-event pause. Consequently, the time taken up by terminal responding increases and the time available for interim activities such as drinking decreases.

Unfortunately this explanation can not satisfactorally account for all of the experimental results. For instance, in the Allen, Porter and Arazie study (1975) drinking only rarely followed a nonfood stimulus even though in that experiment, a substantial pause in lever pressing was observed following the nonfood stimulus. Nor can it account for the absence of drinking in the Porter et al. experiment (1975) when barpressing following the nonfood stimulus was eliminated by retracting the lever for the first 30 secs after the nonfood stimulus. Finally, the absence of drinking during the extinction component in the present experiments can not be reasonably attributed to the suppressive effects of terminal responding since barpressing occurred at low rates in each extinction component.

If drinking is more readily facilitated by food than any other stimulus signalling a S^- period, as these studies consistently demonstrate, and if no explanation is available to adequately incorporate these data within the framework of Staddon's account, these results strongly imply that a "special relationship" exists between eating and drinking and support interpretations of schedule-induced polydipsia which elaborate on the nature of this relationship.

There are many accounts of polydipsia which have included this notion of a special relationship between eating and drinking such that drinking (as opposed to other activities) is uniquely facilitated by intermittent presentations of food. This general theme is illustrated for instance, in explanations of polydipsia which suggest that (a) the ingestion of food leaves the rat's mouth dry and therefore stimulates thirst receptors (Stein, 1964), (b) drinking is a response to thermal imbalance (Carlisle, 1973), and (c) ingestion of a pellet increases body fluid osmolality which elicits drinking (Deaux, Sato & Kakolewski, 1970).

Each of these accounts predicts that drinking is uniquely facilitated above baseline levels by intermittent presentations of food. Although a wide range of responses have been shown to occur in addition to, or instead of, drinking, there is at least some evidence to suggest that drinking maybe the <u>only</u> activity that is induced or facilitated relative to its baseline level by intermittent presentations of food. In a recent experiment, Roper (1981) found that activities such as grooming with periodic presentations of water and exploration on food schedules occupied the early of "interim" part of the interreinforcement interval. However, neither of these activities was enhanced relative to baseline levels.

In general, studies with combinations of reinforcers and activities, other than food and drinking, have either failed to obtain schedule-induction or yielded equivocal results. These experiments include drinking with electrical stimulation of the brain as the reinforcer (Ramer & Wilkie, 1977); drinking in pigeons with food reinforcement (Shanab & Peterson, 1969) and eating in rats with water reinforcement (King, 1974).

Although it would be rash to conclude from these results that drinking is unique as a non-terminal schedule-induced activity, they do challenge Staddon's contention that the expectation of nonreinforcement in the interim part of the interval facilitates a wide variety of activities above baseline levels. Unfortunately the majority of studies have not included baseline conditions and have not precisely reported the temporal location of the activity within the interreinforcement interval.

At present, the results showing that drinking occurs less reliably after nonfood stimuli and those suggesting that the induction of other activities may not be as common as previously supposed strongly favor interpretations of schedule-induced polydipsia that incorporate the notion of a special relationship between eating and drinking. These results are contrary to Staddon's (1977b) account of schedule-induced behavior.

The Differences between Drinking and Wheel Running

The results of the present experiments suggest that while drinking might be characterized as a S^{-}_{food} activity, running occurs in S^{-} periods signalled by stimuli other than food. Consistently high levels of running were observed in the extinction component compared to the food component of the multiple schedules. In transition from a VI-only schedule to a Mult VI/EXT schedule, running was reallocated from the food component to the extinction period. It seems therefore that running, unlike drinking, is an activity that occurs during S^{-} times dissociated from food.

The finding that drinking and wheel-running differ in the extent to which they can be allocated to S^{-} times dissociated from food is also confirmed in other experiments (Hinson & Staddon, 1978; Penny & Schull, 1977). In the experiment by Penny and Schull (1977) rats were exposed to a schedule in which some S^- times were initiated by a food presentation (S^-_{food}) and others by a light (S^-_{light}). When rats were given concurrent access to a water bottle and running wheel, drinking occurred primarily in S^-_{food} intervals while running predominated during S^-_{light} intervals.

In addition to this evidence, there are other experimental manipulations that influence so called interim activities, such as wheel running and drinking, in different ways. For example, running increases when intermittent food is discontinued whereas drinking is eliminated (Penny & Schull, 1977; Staddon & Ayres, 1975). In a procedure where food is allotted on a CRF schedule in the early seconds of the session, drinking decreases as a function of time since eating whereas the opposite relationship is observed between eating time and running (Penny & Schull, 1977). It is also well known that the rate of drinking increases with the rate of food delivery on various schedules, whereas the rate of running decreases as food rate increases (Staddon, 1977b).

In addition to these differences, drinking and wheel running consistently occupy different parts of the interval between food deliveries. Drinking occurs immediately after the delivery of food and running typically occurs later in the interval, at times more distant from the delivery of a pellet. When both activities are concurrently available, drinking follows eating, while running follows drinking. It is not uncommon for wheel activity, unlike drinking, to occur in alternation with unreinforced lever pressing, as the time for food delivery approaches (Levitsky & Collier, 1968; Smith & Clark, 1974).

There is at least some evidence to suggest that drinking and wheel running are not the only "interim" activities that have different functional properties. Penny and Schull (1977) have argued that attack behavior in pigeons and rats shows properties similar to those associated with running (cf. Gentry & Schaeffer, 1969; Huston & DeSisto, 1971). Knutson and Schrader (1975) found that aggression occurred after drinking when both activities were concurrently available and at later post-food times when other activities were not available. Other activities such as gnawing and the ingestion of wood shavings are, according to Penny and Schull (1977), more similar to drinking.

These differences in "interim" activities call into serious question Staddon's assumption that all such activities can be included within a single class of behavior with comparable functional properties. The results of the present experiment suggest that it may be experimentally more useful and theoretically more correct to subdivide nonterminal activities into two categories: (a) those activities such as drinking which are associated exclusively with S^-_{food} occasions and (b) those activities such as running that may occur during S^- occasions dissociated from food. There is at least some evidence (Innis & Honig, 1979) that pigeon's behavior during the postreinforcement pause of FI schedules may be similarly subdivided into two categories.

The importance and usefulness of this division of nonterminal activities can be illustrated in regards to Staddon's time allocation model of contrast.

Behaviors that can be induced by S^- occasions dissociated from food are particularly important for Staddon's account of contrast since the effect depends, according to the time allocation model, on the reallocation of activities from the S^+ to the S^- component of the multiple schedule. Since the results of the present experiments indicate that not all interim activities are similarly reallocated to S^- times dissociated from food, the contrast effect observed in Experiment 3, or any other experiment, must depend on the presence of an activity such as running that can occur in a S^- time dissociated from food (e.g., S^-_{light}). The results of Experiment 3, like those of Jacquet (1974), suggest that the term "contrast effect" can refer not only to increases in barpressing or other terminal behavior, but that similar changes also occur in other nonterminal behaviors such as drinking. Furthermore a nonterminal contrast effect is most likely to be associated with S^-_{food} activities such as drinking. Lastly, the outcome of a contrast experiment may be further complicated by the possibility that the presence of a strong competing S^-_{food} activity such as drinking may actually interfere with a large and reliable increase in terminal responding.

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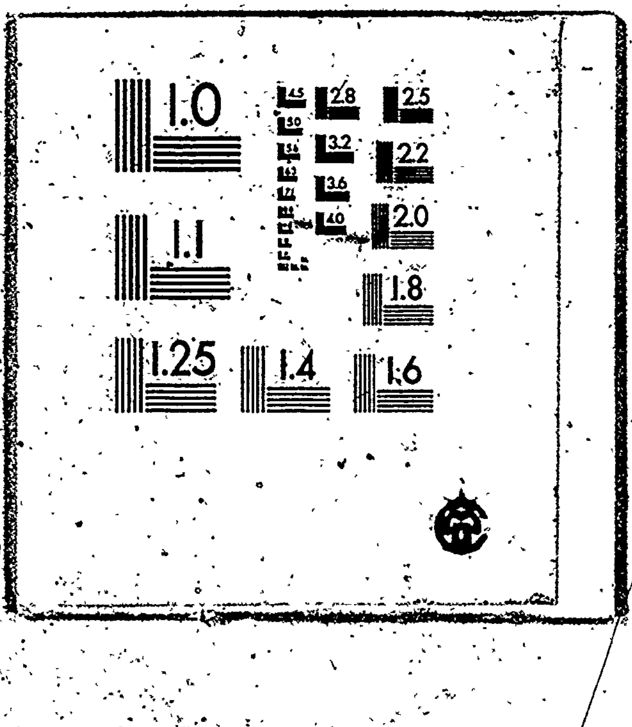

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