SOCIAL REINFORCEMENT AND
DIURNAL RHYTHMS IN BABOONS

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ABSTRACT

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The frequency with which one monkey opened a door for two minutes of visual and physical contact with another monkey was examined as a function of several experimental procedures. In the first series of manipulations removal of the second monkey allowed a comparison between the effects of the social reinforcing object and the effects of the non-social stimuli incidental to delivery of the social reinforcer. During daily four-hour sessions, reinforcement rates (number of door openings/unit time) with a monkey in the adjacent cage averaged several times those when no monkey was in the adjacent cage. Removal of the second monkey did not significantly affect rates of food and water reinforcement, but removal of food and water contingencies did increase rates of door opening to an empty cage. Idiosyncratic factors contributed to above-zero rates when the cage was empty. For example, one subject's empty-cage rates were halved, and his amount of stereotyped rocking nearly stopped, by a wall placed next to the door. The existence of pertinent variables peculiar to the individual subject and to the particular apparatus directs attention to the necessity of control procedures.

In the second set of conditions two baboons lived in the cages 24 hours a day and were under continuous illumination, as they had been for several months. During a short initial period when either monkey could open the door, and in a second longer period when only one could open the door, the monkeys had a very regular day length

of approximately 14 hours, which remained synchronous with clock time. The experiment did not identify the pertinent elements entraining the monkeys' activities. This persisting alignment with clock time under reasonably stable conditions suggests that the entraining environmental stimuli were more subtle than those demonstrated in the literature.

The monkeys also revealed a distinctive patterning of frequency of social contact as a function of time of day. The distribution had a midmorning peak, a midday low, and a minor afternoon peak, the same pattern recently documented as occurring in troops of wild baboons. This pattern was only barely noticeable in distributions from individual days, and became significant only when averaged across days. To a lesser degree, similar patterns were evident in distributions of food and water reinforcement rates.

In the final set of procedures two levels of food deprivation, two levels of social deprivation, and two times of day were produced by alternating the subjects in morning and afternoon sessions, by conducting only morning or only afternoon sessions, and by pre-feeding and "pre-socializing" in a sequence designed to contrast the effect of one condition against another. Regardless of deprivation of social or other reinforcers, the subjects displayed a higher rate of social reinforcement in the mornings than in the afternoons. An early morning "pre-socializing" session slightly lowered the usual morning rate of social reinforcement, but preceding an afternoon session with a morning session, an early morning and a morning session, or by no session since the previous afternoon, had no effect on the afternoon social reinforcement rates. Independence of social reinforcement rates from variations in food deprivation, and low frequencies of eating with the door open implied that the presence of food did not appreciably affect rates of social reinforcement.

These studies established social reinforcement under controlled laboratory conditions as a strong reinforcer capable of maintaining behavior over long periods of time, and elucidated a pertinent variable in social reinforcement, that of diurnal rhythms.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

GENERAL INTRODUCTION

Diurnal rhythms, or more generally, circadian (Halberg, 1960) periodicity, is one of the most pervasive phenomena in biology. Circadian periodicity permeates such diverse endeavors as geophysics and psychiatry. It appears as a dominant feature throughout the phylogenetic scale from unicellular Euglena and Paramecium through multicellular plants, insects, fish, reptiles, birds, and mammals, especially rodents, to man (Sollberger, 1965). As documented by Bunning (1964) it is manifest in as great a variety of functions: luminescence of Gonyaulax, CO_2 production of Bryophyllum, leaf movements of Phaseolus multifloras, sporangia discharge of Pilobus sphaerosporus, pupal emergence of Drosophilia, motoric activity of isolated hamster gut, microfilarial activity, locomotor activity in nearly all insects and vertebrates, and a host of physiological changes in man and other mammals such as liver activity, eosinophil level, body temperature, urine volume, excretion rate of hormones and body salts, pulse rate, metabolic rate, ventilation, mitotic activity, and susceptibility to toxic agents. These lists are not meant to be exhaustive but rather are just meant to establish the breadth and depth of the phenomena.

As a concomitant of such extensive physiological periodicity, one might expect behavioral variation. However, findings on daily cyclical effects of human abilities have shown considerable inconsistency (Kleitman, 1949, 1963; Freeman & Hovland, 1934), and the observations in nearly all studies on animal subjects have been limited to gross activity as measured by a stabilimeter or running wheel.

In contrast to the usual biological emphasis, the present thesis documents the daily patterning of a certain class of behavior, social behavior, and suggests time of day as a possible important determinant of baboon social behavior. The last few years have seen intensive effort expended by several investigators on primate social behavior (Mason & Riopelle, 1964). The analysis of social interactions in terms of reinforcing stimuli by Skinner (1953) occasioned an outburst of research testing this stimulating approach, beginning with Greenspoon's (1955) verbal reinforcement study and the Gewirtz and Baer (1958) studies of social deprivation. Falk (1958) first applied the concept to animal behavior by demonstrating that offering an arm for grooming to a chimpanzee reinforced learning of a discrimination. Mason, Hollis & Sharpe (1962) subsequently showed that chimpanzees preferred play and being groomed, over grooming. Angermeir (1960) attempted to quantify degree of social reinforcement when he compared the effectiveness of visual, partial physical, and full physical social reinforcement in group-reared and isolate-reared rats.

Many of these studies and more recent ones have failed to produce results compatible in every respect with predictions made from a knowledge of the effects of food reinforcement on behavior. A social reinforcer may differ in many important respects from food reinforcers. A notable point is the drastic difference between maximum deprivation durations of the two reinforcers. Many organisms can continue living in isolation, but few can continue long without food. At least two studies indicate that certain forms of social reinforcement may, like novelty, rapidly habituate (Stanley & Eliot, 1962; Stanley & Morris, 1965). Another implies that they are ephemeral and insubstantial, requiring association with other reinforcers to maintain their reinforcing properties (Mason, 1961).

The present thesis presents three studies exploring possible determinants of primate social behavior within the context of social reinforcement. This was accomplished by requiring a bar-press response to open a motor-driven door, which revealed a second monkey in an adjacent cage. The technique preserved some of the physical-temporal relationships recently noted as important for maintaining non-food reinforcement conditions analagous to food reinforcement conditions (Gibson, Reid, Sakai, & Porter, 1965). In addition, this technique allowed automatic delivery of the social reinforcer and collection of data in an area notoriously resistant to such an approach (Bernstein, 1964). The duration of the social reinforcement was defined as beginning when the door started to open, and ending when the door closed. It was described as social since the presence of the second monkey was an important source of stimulation maintaining door-opening behavior.

The thesis demonstrates that social reinforcement can be continuously effective over long periods of time, and elucidates a pertinent variable in social reinforcement, that of diurnal rhythms. The first study, a control study, establishes the reinforcing stimuli as being primarily social rather than incidental stimulation associated with the door movement. The second study reveals a daily patterning of social activities, with a midmorning peak, and the third study suggests that the phase of the diurnal cycle interacts with the effect of social isolation.

CHAPTER II

COMPARISON OF SOCIAL AND NON-SOCIAL REINFORCING STIMULI

Introduction

With burgeoning interest in the reinforcing aspects of social interaction, a technique has become popular which might be viewed as an "automatic social reinforcement dispenser," analogous to the solenoid or motor operated automatic food reinforcement dispenser so common now. The social dispenser device consists merely of a manually (Butler, 1953) or motor (Mason, 1961; Angermeir, 1960) operated door, which when operated by some convenient response reveals the reinforcing object on the other side. The stimulus object may be inanimate or another organism of the same or alien species varying along any of a number of desired dimensions.

A complication arises from use of the primate subject. Since monkeys manipulate a variety of objects very readily (Harlow, Harlow & Meyer, 1950; Harlow & McClearn, 1954), this tendency alone would be expected to produce a high operant level of a bar-press response. In addition, the response produces the auditory stimulation of the door opening, the visual stimulation of the moving door, and once open, an expanded visual and tactual area. With all the research documenting increased responding maintained by these kinds of reinforcing stimuli (Butler, 1963), it is certainly conceivable that social aspects may add little strength to the stimulus complex which maintains door-opening behavior. Therefore, to determine the effect of these variables incidental to delivery of the social reinforcer, the following control experiment was performed. A comparison between social and non-social reinforcing stimuli was obtained by removing the second monkey from the adjacent cage for several days and then returning him. Additionally, food and water intake were monitored, and manipulated once, in order to observe a possible interaction among non-social reinforcers.

Method

Subjects. Two 20-pound preadolescent baboons (Papio papio), one male (MB) and one female (FB), and a mature 19-pound male Sooty Mangaby (MM) were subjects. They were maintained on ad libitum Dietrich & Gamble 0.67-gram standard monkey pellets and water. All had several months of previous experience on complex chained FI, VI, and FR schedules of food, water, and social reinforcement in this apparatus. The subjects were familiar with each other as a result. Overnight they were transferred to separate home cages.

Apparatus. The experimental chamber consisted of two adjacent cages each approximately 2 feet square separated by 3/8-inch diameter steel bars 4 inches apart and a motor driven guillotine door, 20 inches high and 16 inches wide which required 7-1/2 seconds to open or to close. Statements of how long the door was open include this 15 second door transit time. One of the cages contained three levers spaced horizontally on the wall opposite the door which delivered food, water, or opened the door, respectively. This cage was labeled the active cage. The bare adjacent cage was labeled the passive cage. The chamber was in a continuously lighted sound-resistant cubicle estimated to attenuate 12-24 db. in the audio spectrum. A large air blower provided additional masking. The programming and recording apparatus, located outside the experimental room, recorded responses, reinforcements, and whether the door was open or closed on a combination cumulative response and event recorder, and recorded reinforcements and how long the door was open on digital counters. Responses made during receipt of reinforcement were not recorded.

A closed circuit television camera directed at an angle down through the glass top of the active cage allowed observation of one subject when the door was closed and both subjects when the door was open. Observations were generally made at the beginning and end of sessions, and irregularly during sessions. Temperature was stabilized by drawing large volumes of cool outside air from beneath the building with a blower and warming it to approximately 25° C with a thermostatically controlled heater. Frequent observations of a thermometer in the room confirmed the system's stability.

Procedure. Fixed ratio schedules of reinforcement were in effect on each of the three levers. That is, a certain fixed number of lever depressions (responses) were required to produce reinforcement. On the left lever this ratio of responses to reinforcements was 50 (an FR 50 schedule), and the reinforcer was 50 food pellets. On the center lever each 25 responses (FR 25) produced 50 ml of water. On the right lever 10 responses were required (FR 10) to open the door between the cages. After three minutes the door automatically closed. The previously mentioned experience of these subjects suggests that they discriminated well between the functions and response requirements of the levers.

All food, water, and social contact (except auditory) between subjects was obtained during four-hour long morning, afternoon, or evening sessions. More specifically, MB served as subject in the active cage while either FB or MM served as the social reinforcing object in the passive cage during morning sessions which began at 9 a.m. ±30 minutes. During afternoon sessions, beginning at approximately 1 p.m., MM was in the active cage and either MB or FB in the passive cage. During evening sessions, beginning at approximately 5 p.m., FB was in the active cage and either MB or MM in the passive side. The subjects had been trained to enter a small cage for transfer from active to passive or home cages. Infrequently, transfer was forced by prodding.

Training, control, and extinction phases were divided into six periods of varying length as outlined in Table I and the following paragraph.

The general regime described above was followed for 12 days, the first days, with considerable procedural variation, constituting a training and adjustment period, and the latter days constituting the initial control condition (social$_1$). The shorter social condition for monkey MB resulted from an apparatus failure. The first non-social condition (door) consisted of not putting a subject in the passive cage, but otherwise leaving conditions unaltered, the door still opening upon completion of the fixed ratio requirement. Simultaneously with the beginning of the door condition the fixed ratio requirement to open the door was mistakenly reduced from FR 10 to FR 5. Possible effects of this schedule change are considered in the discussion section. After five days the subjects, instead of being housed in the experimental room between sessions, were moved to home cages in a nearby room. Then, food and water contingencies, in addition to social, were removed. The door still opened (condition "door only"). During this time the subjects were fed and watered in their home cages for at least 30 minutes before and several hours after each session. For one day a

Condition	Number of Sessions	
	FB & MM	MB
training	7	8
social$_1$	5	4
door	6	7
door only	3	2
wall	1	1
social$_2$	3	3

Table I. Sequence and Durations of Procedures metal wall, like the other walls of the cage, was inserted next to the other side of the door. Finally, the original conditions were reinstated with a subject in both active and passive cages except that the requirement to open the door continued at FR 5 (condition social$_2$). It was not returned to FR 10.

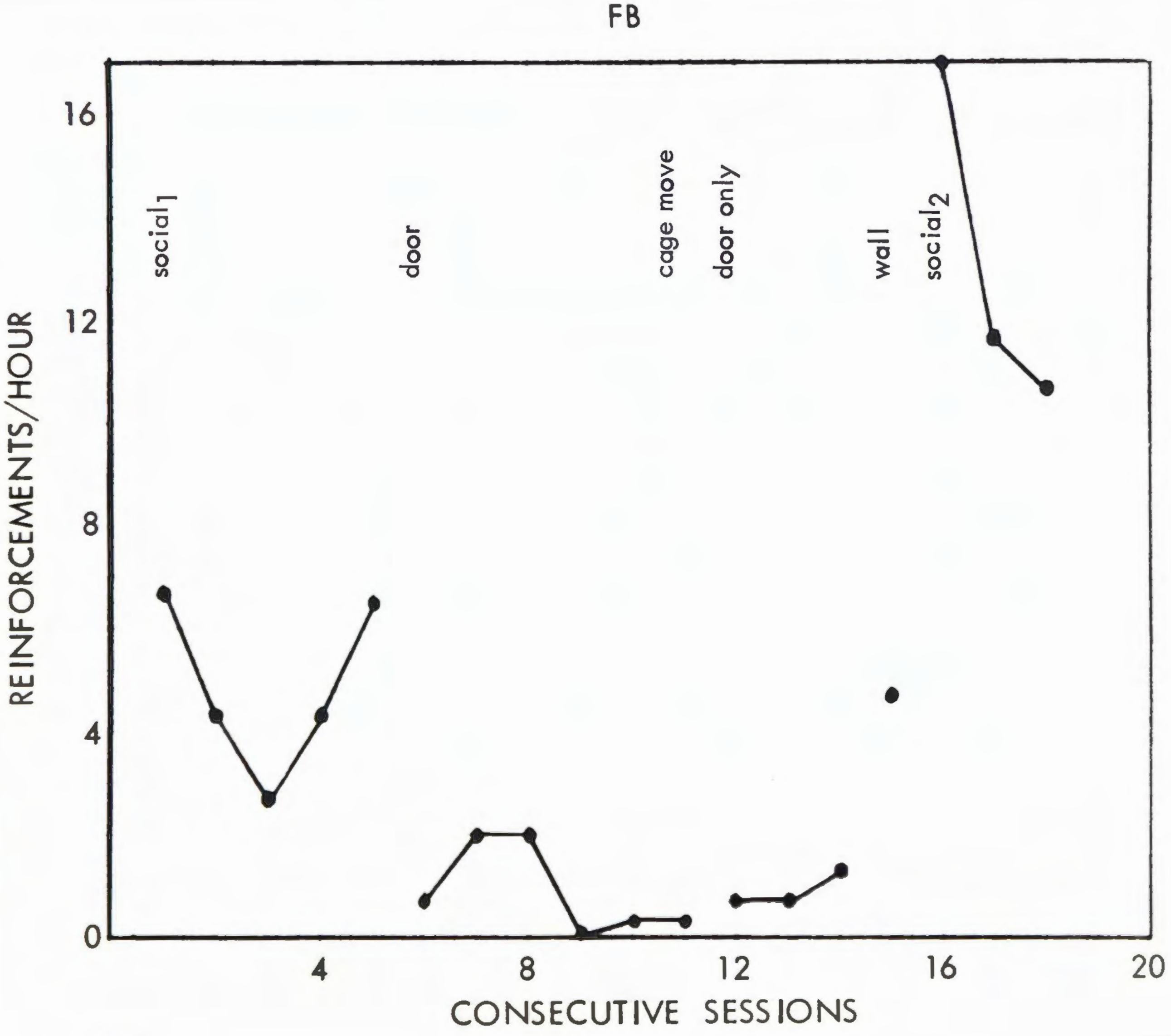
Results

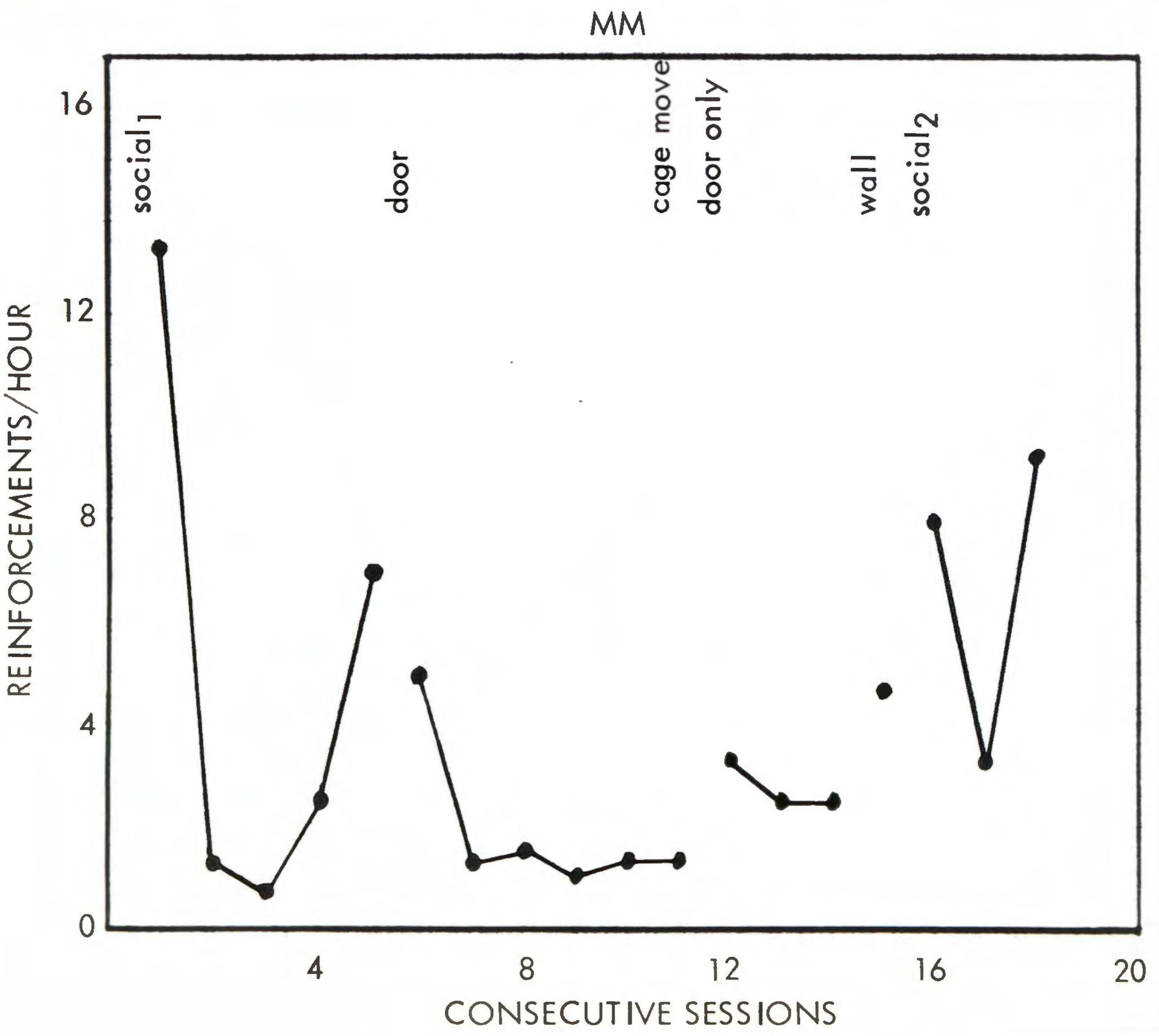
The index of the subjects' tendency to obtain social or non-social reinforcement was reinforcement rate, the number of times per hour the door was opened. Figures 1, 2, and 3 present daily reinforcement rates for individual subjects as a function of each condition. Statistical tests of significance for differences between various conditions were applied first to the data of the individual subjects. The individual comparisons listed in Table II were found to be significantly different ($p < .05$) by the two-tailed Mann-Whitney U test (Siegel, 1956, pp. 116-127).

The comparisons of primary interest are between the conditions with social reinforcement and the comparable condition without social reinforcement. These are the first two in Table II. The number of observations on individual subjects was insufficient for comparison 3 to reach statistical significance. Therefore the individual data were combined and tested with the two-tailed randomization test for matched pairs (Siegel, 1956, pp. 88-92). The result of this comparison was significant ($p < .05$). Comparison 4 for the grouped data of subjects MB and FB was similarly significant.

After the first day for subjects MB and MM, and after the first three days for FB, the door condition reinforcement rate remained at a steady, low level below that of the succeeding "door only" condition ($p < .05$ two-tailed randomization test).

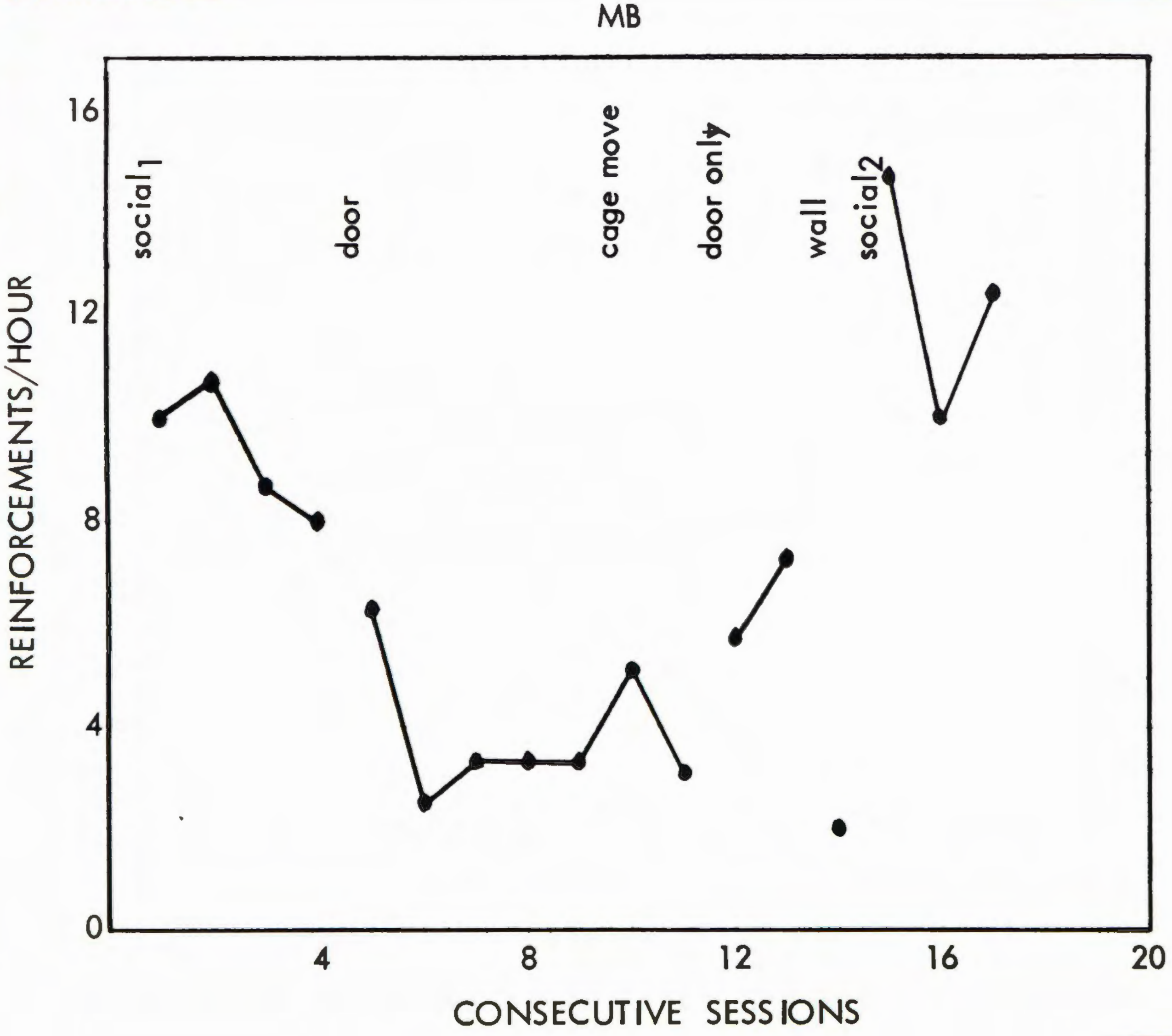
Fig. 1. Daily reinforcement rates for subject FB.


FB
social1
door
cage move
door only
wall
social2
REINFORCEMENTS/HOUR
0
4
8
12
16
CONSECUTIVE SESSIONS
4
8
12
16
20



MM
social1
door
cage move
door only
wall
social2
REINFORCEMENTS/HOUR
16
12
8
4
0
4
8
12
16
20
CONSECUTIVE SESSIONS

Fig. 3. Daily reinforcement rates for subject MB.


MB
REINFORCEMENTS/HOUR
0
4
8
12
16
CONSECUTIVE SESSIONS
4
8
12
16
20
social1
door
cage move
door only
wall
social2

Comparison	Subjects Attaining Significance ($p < .05$)		
1. social$_1$ vs. door	MB	FB	
2. door vs. social$_2$	MB	FB	MM
3. door only vs. social$_2$			
4. social$_1$ vs. social$_2$		FB	

Table II. Individual Comparisons Between Conditions

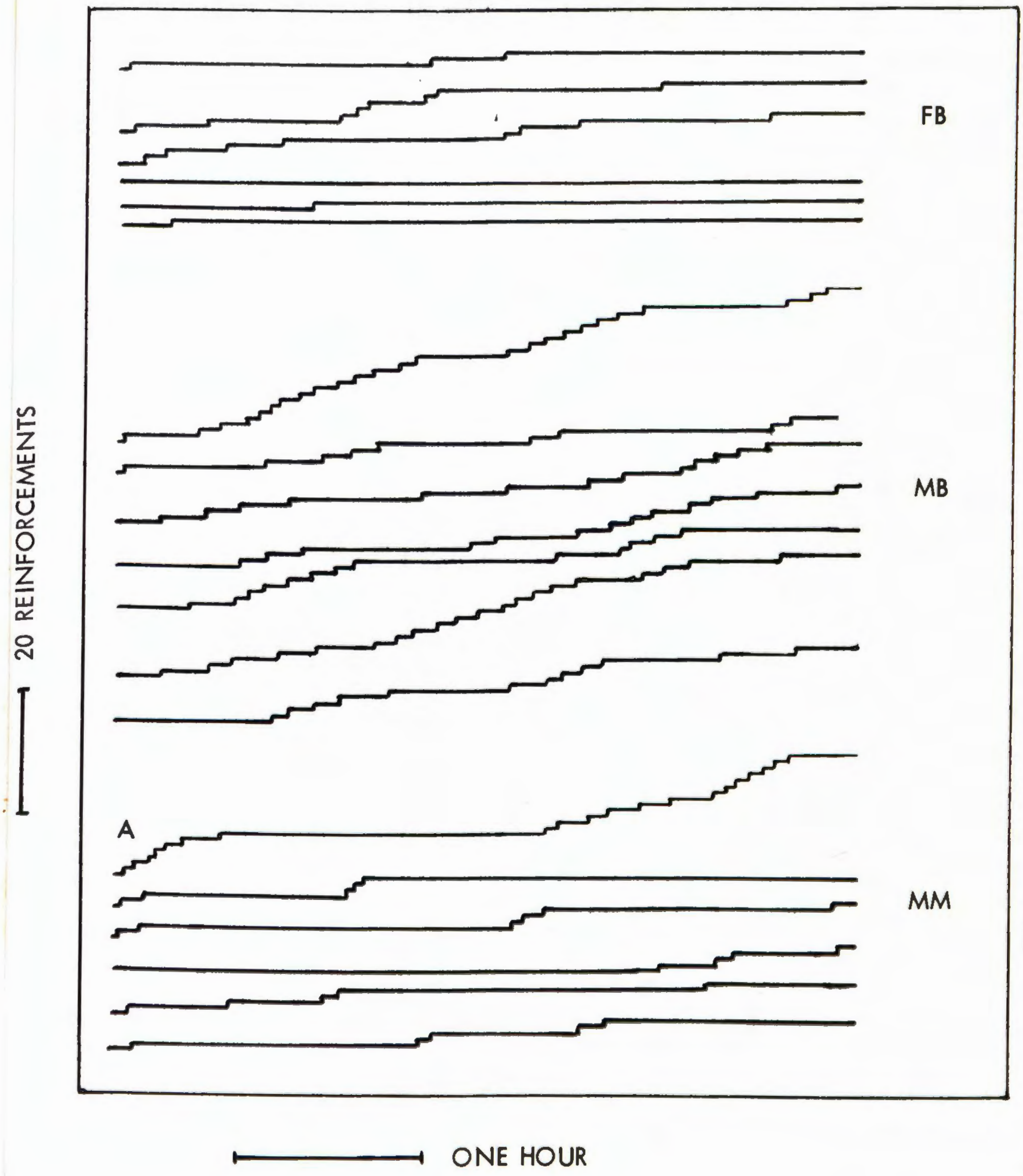
Although a transition period is to be expected following such a change (Zeaman, 1949; Ferster & Skinner, 1957, pp. 63-66; Sidman, 1960, pp. 281-316; Kimble, 1961, pp. 122-124, 281-327; Stanley & Morris, 1965), it should be noted that the specification of its duration was made a posteriori.

No distinct within-sessions effect under the door condition appears in the cumulative reinforcement records of Fig. 4. These records were drawn by hand from event record data. Subject MM on the first day of the door condition showed a higher initial rate (point A) and then cessation, but began again 2/3 of the way through the session. Because of the finite time interval required for reinforcement, the slope at point A represents a near maximal rate.

The difference in variability between the social condition and the non-social conditions was as definite as the difference between the means. As can be seen in figures 1, 2, and 3, the only marked day to day deviations in the non-social conditions are attributable to change from one condition to another. These may be contrasted to the range of 2.7 to 17.0 reinforcements/hour shown by FB during the social conditions.

During the door condition MB was observed peering through a space, made by the door opening, at the other two subjects housed in the same room. Neither FB nor MM were ever observed doing this during their sessions. When, after five days of the door condition, the monkeys' home cages were moved to another room, MB responded even more the first day after the change, and then returned to his previous rate the second day. Moving the cages produced no change in rate by the other two subjects, nor would it be expected to, since they apparently had not been looking through the space.

Fig. 4. Cumulative number of reinforcements during the door condition for each monkey. The lines represent sessions arranged consecutively from top to bottom.


FB
MB
A
MM
20 REINFORCEMENTS
ONE HOUR

During door and door only conditions MB opened the door at least twice as frequently as the other monkeys and executed a stereotyped rocking movement when it was open. The difference between the door and the other sides was reduced by installing a wall on the other side of the door. This modification produced the lowest rate by MB and very nearly stopped the stereotyped rocking. The other two monkeys reacted very differently, with higher rates. They were observed scraping off the fresh paint on the new wall with their teeth and fingernails and eating it.

Only incidental observations were made of interaction effects between reinforcers, and that only during non-social conditions. Removing food and water reinforcement contingencies doubled door opening rates for all subjects (figures 1, 2, & 3, door only). Removing the social reinforcer (door condition) produced only insignificant increases in the mean number of food pellets eaten per session by MB and MM, 288 vs. 316 and 186 vs. 224 respectively, but no change by FB, 333 vs. 332. When social reinforcement was reintroduced, only MB reduced his eating, to 225 ($p < .05$, two-tailed Mann-Whitney U), and FB and MM continued approximately as before, consuming 325 and 217 pellets respectively.

Discussion

Simultaneously removing the social reinforcer and changing the social fixed ratio requirement makes interpretation of the results somewhat difficult. However, reduction of a fixed ratio is usually followed by an increase in reinforcement rate, not a decrease (Ferster & Skinner, 1957). Therefore, the ratio reduction would normally have had an effect contrary to the decrement actually observed. In other social reinforcement studies absence of the reinforcing subject usually results in lower measures than its presence (Butler, 1954, 1958; Stanley & Morris, 1965). Apparently, the effect of the small ratio change was relatively insignificant and overridden by the change in the reinforcement variable which produced the expected decrease.

Attributing the difference between the first and second social conditions to the intervening 10 days of social deprivation is also complicated by the difference in the work requirements. Considering the subjects' past history and the length of the sessions, it would seem that five responses requiring approximately a second to emit, might make little difference. Nonetheless, under many experimental conditions, reinforcement rate is closely related to the fixed ratio requirement (Boren, 1953; Ferster & Skinner, 1957). Particularly if the reinforcer is weak, capable of maintaining only small amounts of behavior, small changes in the ratio requirement could greatly affect reinforcement rate (Ferster & Skinner, 1957).

Comparison of the social reinforcer removed vs. returned (condition door vs. $social_2$) unequivocally shows that higher rates occur when another monkey is present. This result provides the main evidence that the reinforcement is actually social in nature, dependent upon another organism, and more potent than the visual and auditory reinforcement of the door and adjacent cage.

Results similar to these were anticipated by Butler's (1954) experiment with visual and auditory reinforcers, by Angermeir's (1960) referral to unpublished data from socially reinforced rats, by rhesus monkeys opening doors to a rat only after having lived with it (Mason & Green, 1962), and by Stanley and Morris' (1965) studies with a passive person reinforcer for dogs. These and other previous experiments have included only brief exposure to the reinforcer. Such designs emphasize whatever "novelty" effects may be present, making the results difficult to distinguish from "social" effects. Both within-session effects and between-session effects, which are indicative of novelty, are not uncommon and two studies have reported rapid habituation of a social reinforcer (Stanley & Elliott, 1962; Stanley & Morris, 1965). In the present study both the physical arrangement and the longer exposure periods allow greater opportunity for social interactions to occur, and for "novelty" effects to decrease.

The wide difference in variability of reinforcement rates between social and non-social reinforcement periods probably reflects the difference in regularity of reinforcement between the two conditions. A similar difference in variability between social and non-social conditions was reported by Butler (1954). With the social reinforcer absent the empty cage was always the same, but with a social reinforcer present the stimuli following door opening ranged from being groomed to being bitten. Such variation is inherent when, as under the conditions of this experiment, the exact stimuli comprising the social reinforcers are left free to vary so widely. Perhaps the variation deterred habituation. However, the variability in MM's social responding, possibly due to a species difference, led to his abandonment in the succeeding studies.

During the door condition, MB's rate was considerably higher than the rates of the other two subjects. If induction from the food and water reinforcement contingencies was occurring, then removal of these contingencies during the door only condition would have been expected to result in a decrease in MB's higher rate. Instead, reinforcement rates increased for all three subjects. This might have reflected the increased variability typical in extinction, but the subjects were freely fed and watered in their home cages, and a decrease would still have been expected by the second or third day. An alternative interpretation is that food and water consumption interfered with the weaker behavior of door-opening. This possibility is consistent with the observation that removal and return of the social reinforcing subject made relatively little change in the frequency of the ingestive behaviors. Probably any situation restricting the subject's attention and activities will produce higher "spontaneous," "operant" or "extinction" response levels.

Since MB seldom executed the stereotyped rocking movement while facing anywhere but the passive cage, it seemed possible that some stimuli associated with the open door were affecting this behavior. Limiting the stimuli to just the door movement itself, by installing a wall just on the other side of the door, greatly reduced the frequency with which he opened the door and rocked. Whether the larger open visual area or engaging in the stereotyped behavior was the more important is unknown.

Since some of the factors that can affect door opening are peculiar to the apparatus and idiosyncratic to individual subjects, a non-social control procedure appears necessary whenever the investigator makes comparisons in absolute rather than relative terms, or between different subjects, procedures or apparatus.

CHAPTER III

FREE RUNNING PERIODICITY

Introduction

Daily behavioral cycles of several primate species in their native state has been documented (Mason & Riopelle, 1964). For example, chacma baboons customarily spend the early afternoon sleeping or being relatively inactive (DeVore, 1962). While these observations were made under normal day/night cycles of light and temperature, a recent experiment in the laboratory without cycles of illumination and temperature revealed a weak circadian rhythm in chimpanzees' feeding behavior and body temperature (Rohles, et al, 1963a,b). Other primates exhibit diurnal wake/sleep rhythms even under continual illumination in the laboratory, but the assumption has been made that this was probably due to "anchoring" by regular feeding times and daily noise and activity cycles around the laboratory (Boren, 1960).

In the following study, two baboons were given free access to each other continuously, 24 hours a day, since such an unrestrained experimental condition is most likely to allow appearance of a circadian rhythm. In addition, an ad libitum social environment provides information on maximum social reinforcer consumption analogous to ad libitum food reinforcement.

Experiment 1

Subjects and Apparatus. The subjects were MB and FB of the previous experiment. The apparatus was also the same except that the subject in the "passive" cage, FB, had direct access to a hopper of Dietrich & Gamble pellets and a water bottle. The subject in the "active" cage, MB, still had to press one of three levers in order to obtain food, water, or to open the door. FB, the subject in the passive cage, could open the door by pressing a button from the second day on.

Procedure. This procedure immediately followed that described in Chapter II. The subjects were continuously illuminated by a 200-watt overhead light as they had been for some months previously and were kept under the same conditions as in the previous experiment. The experimenter entered the room irregularly, an average of three times each day, always between the hours of 7 a.m. and midnight, to supply fresh food, water, and sawdust, and to observe the subjects. MB lived in the active cage and FB in the passive cage. An FR 1 was required of either monkey to open or to close the door. The door remained open until closed by either of the subjects, and a response made while it was in the process of opening or closing had no effect. Completion of an FR 5 on the second lever produced 50 cc of water and an FR 10 on the third lever produced 20 food pellets for MB, the subject in the active cage. This procedure was followed for one week. An exception occurred on the second day for five hours when FB's button would not open the door. On the last day, FB's button was again disconnected.

Results

The baboons were awake, as evidenced by the event record and by the experimenter's direct observation, from approximately 5:10 a.m. to approximately 7:10 p.m. MB always awoke first and began responding at very nearly the same time each day, the time on successive days appearing in Table III. The two

Time of First Response (a.m.)		Time of Last Response (p.m.)	Day Length
5:17	to	11:40*	----
6:49	to	11:25*	----
6:30	to	7:24	----
5:09	to	7:45	14 hr 34 min
5:12	to	7:20	14 hr 11 min
5:38	to	6:50	13 hr 12 min
5:10	to	7:10	14 hr 0 min
5:04	to	6:50	13 hr 46 min

Note: Nights the baboons were kept awake late by the experimenter are indicated by (*).

Table III. Onset, Termination, and Duration of Periods of Activity deviant days resulted from the experimenter's making repairs the previous night, keeping the baboons awake very late. The rapid return to 5:15 a.m. awakenings after these disturbances demonstrates the stability of the baboons' diurnal rhythm. They similarly ended with great regularity, resulting in a median day length of 14 hours.

The mean number of times per day the door was opened and closed by each subject, and how long the door was open are shown in Table IV. Inspection of the table shows that when either subject controlled the door, it was open more than 8 hours a day, or approximately 61% of the subjects' waking hours. It was opened from 200 to 400 times a day resulting in a mean duration of 108 seconds, with MB opening about five times as often as he closed, and FB closing about twice as often as she opened. FB made more total door responses than MB, a mean of 366 per day to MB's 185 per day. When MB alone controlled the door, he opened it only 20 times for a mean duration of 30 minutes. Total time open did not change. Inspection of the event record showed that the door was always closed for their inactive or "night" period, being closed by FB five nights and by MB two nights.

From visual observation it appeared that FB very often opened the door whenever MB responded on food or water levers, but this could not be discerned with confidence from the event record because of the time scale. When MB had sole control over the door for five hours, 16 out of 17 bursts of responding on food and water levers occurred while the door was closed. Only one was discernible while the door was closed in the preceding five hours, when FB also could open the door. When MB had sole control over the door on the last day, the same pattern, responding on food and water levers exclusively when the door was closed, occurred only during the last one to two hours of his active period.

Door Control	Responses per Day						Door Open Duration (minutes)	
	MB			FB				
	open	close	total	open	close	total	per day	per response
MB & FB	154	31	185	122	244	366	503	1.8
MB	20	20	40	---	---	---	602	30.1

Table IV. Mean Frequency and Duration of Door Opening

Discussion

This first week of preliminary data revealed a definite, regular diurnal rhythm without being synchronized by a 24-hour light cycle. The finding that MB always awakened first suggests that his diurnal activity rhythm may have been displaced a little earlier than FB's. The precision of the resultant diurnal rhythm was not remarkable when compared to that of the flying squirrel (Glaucomys volans) which has been reported as 24 hours 21 minutes ± 6 minutes under similar lighting conditions (DeCoursey, 1961). However, these squirrels were selected for their rhythmicity. With selection and under more regular conditions for longer periods of time the circadian period of the baboon might be more constant. Further discussion of the diurnal rhythm is postponed until the data of the subsequent experiment can be considered.

If the stimulation of the other animal were reinforcing, why did the baboons close the door at all? Numerous conjectures are possible, but only a few of the most likely will be discussed.

Either MB or FB may have closed the door at times to avoid interference from the other while they ate. The results of Chapter II suggested that MB may have been more susceptible to this influence and the present results are also compatible with such an interpretation. A tendency to eat with the door closed could have developed from a past history in which both subjects were food deprived and eating in front of the other usually led to fighting. Allowing free access to food may have reduced this tendency.

Another explanation is perhaps more appropriate for the majority of MB's and especially FB's door closing responses. The closing of the door often occasioned intense activity at and around the door (Fig 5.) The most frequently observed form of interplay between the baboons was reaching and biting at each other and at the door as it moved, especially as it closed, much in the manner of kittens pawing at each other around an obstacle. Play behavior was reported by Mason, et al (1962) as being the most reinforcing of several forms of interactions for young chimpanzees, and the same appeared to be true for the baboons.

FB may have had a higher total response output on the door button than MB simply because she had fewer manipulanda, an interpretation compatible with the data of Chapter II when removal of food and water contingencies increased door opening.

The next experiment continued examination of circadian variation in social and eating behavior by imposing the additional constraints of one baboon at a time opening the door for a fixed, short period of time.

Experiment 2

Procedure. This experiment was preceded by the first four conditions of Chapter IV. An FR 10 on the appropriate lever produced 10 food pellets, 25 ml of water, or opened the door for 135 seconds. The door closed automatically. Only the subject in the active cage could open the door and neither could close it. A timer began sessions at 4, 5, or 6 a.m., and ended them approximately 18 hours later, long past the time when the subjects quit responding for the day. FB was exposed to this condition for nine consecutive days except that on the second day the door closed irregularly until 11 a.m., and on the sixth day the session began at 9 a.m. MB was exposed to this condition for nine consecutive days except that two days elapsed between the second and third sessions, and on the seventh day the door remained open continuously from

Fig. 5. Typical form of play as the door closed.

2 p.m. to 8 p.m. The initial session for each subject and those in which exceptions to the prescribed regime occurred were not included in the subsequent data analysis. During the first four days that FB was in the active cage, and the fifth, sixth, and ninth days that MB was in the active cage the temperature rose well above the limits of the regulating system, resulting in a circadian temperature cycle with days approximately 6°–10° C warmer than nights. Conditions otherwise were the same as in experiment 1.

Results

The hourly median social reinforcement frequencies as a function of time of day for FB and MB appear in Fig. 6. No responding at all occurred at night, just as in experiment 1. MB stopped no later than 7 p.m., FB no later than 8 p.m. Thus, both slept without interruption until the next morning, following a clearly demarcated circadian pattern. As measured from the event records, MB awoke a mean 0.8 minutes after the sessions began, including the single 4 a.m. start, but FB averaged 19.0 minutes before beginning responding.

Although MB's whole distribution is shifted about one hour earlier than FB's, and begins more abruptly, both distributions exhibit a large morning peak, an early afternoon dip, and a smaller afternoon peak. Daily distributions of the number of social reinforcements show a certain amount of variability, but the main description of the pattern is borne out by nearly every one of FB's daily distributions in Fig. 7.

Friedman's analysis of variance for related samples (Siegel, 1956) for the differences between the morning (10-11 a.m.) peak, the afternoon dip (3-4 p.m.) and the afternoon peak (4-5 p.m.), proved significant at the .03 level for FB's data.

Fig. 6. Average distributions of social reinforcement as a function of time of day.

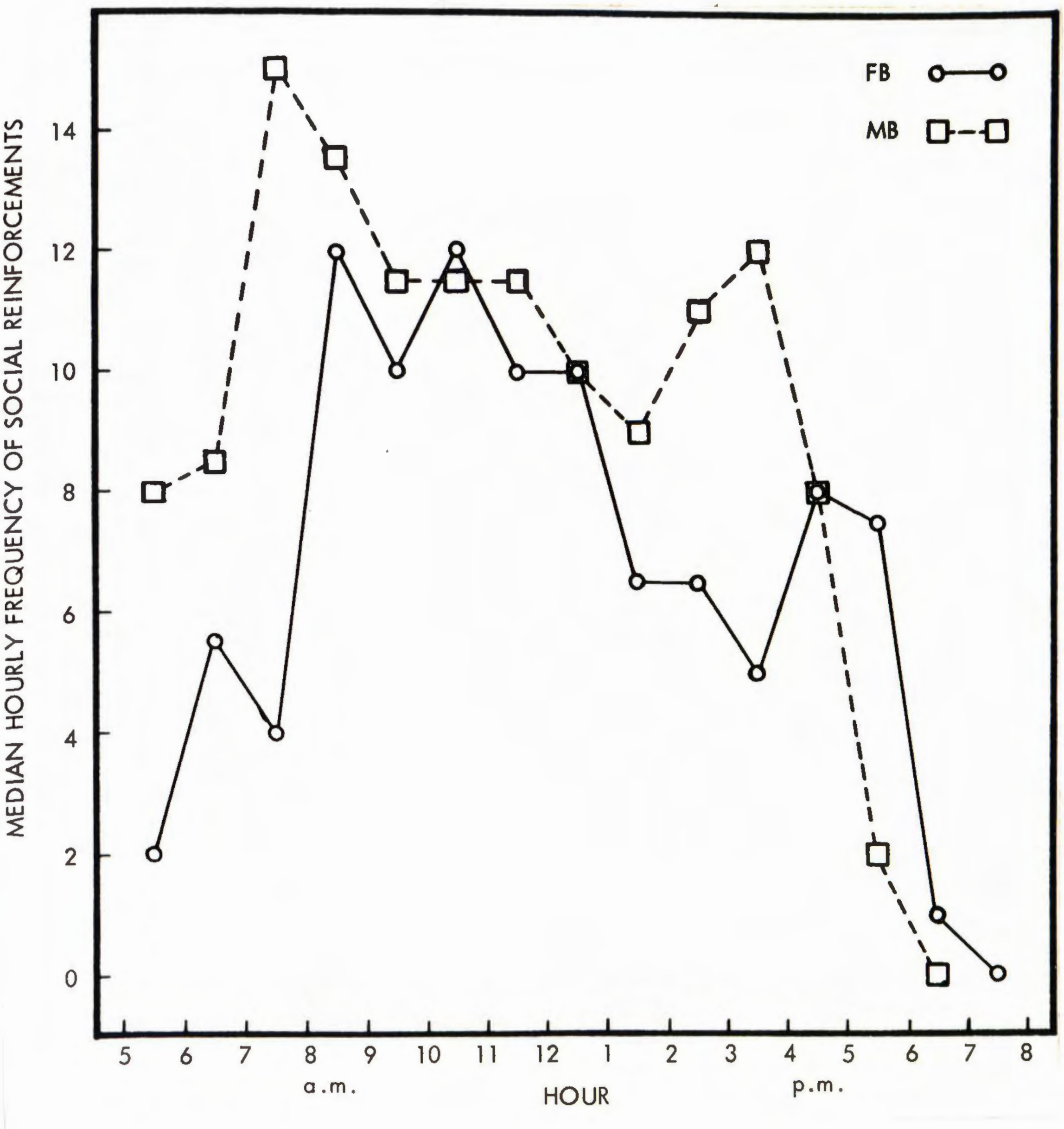
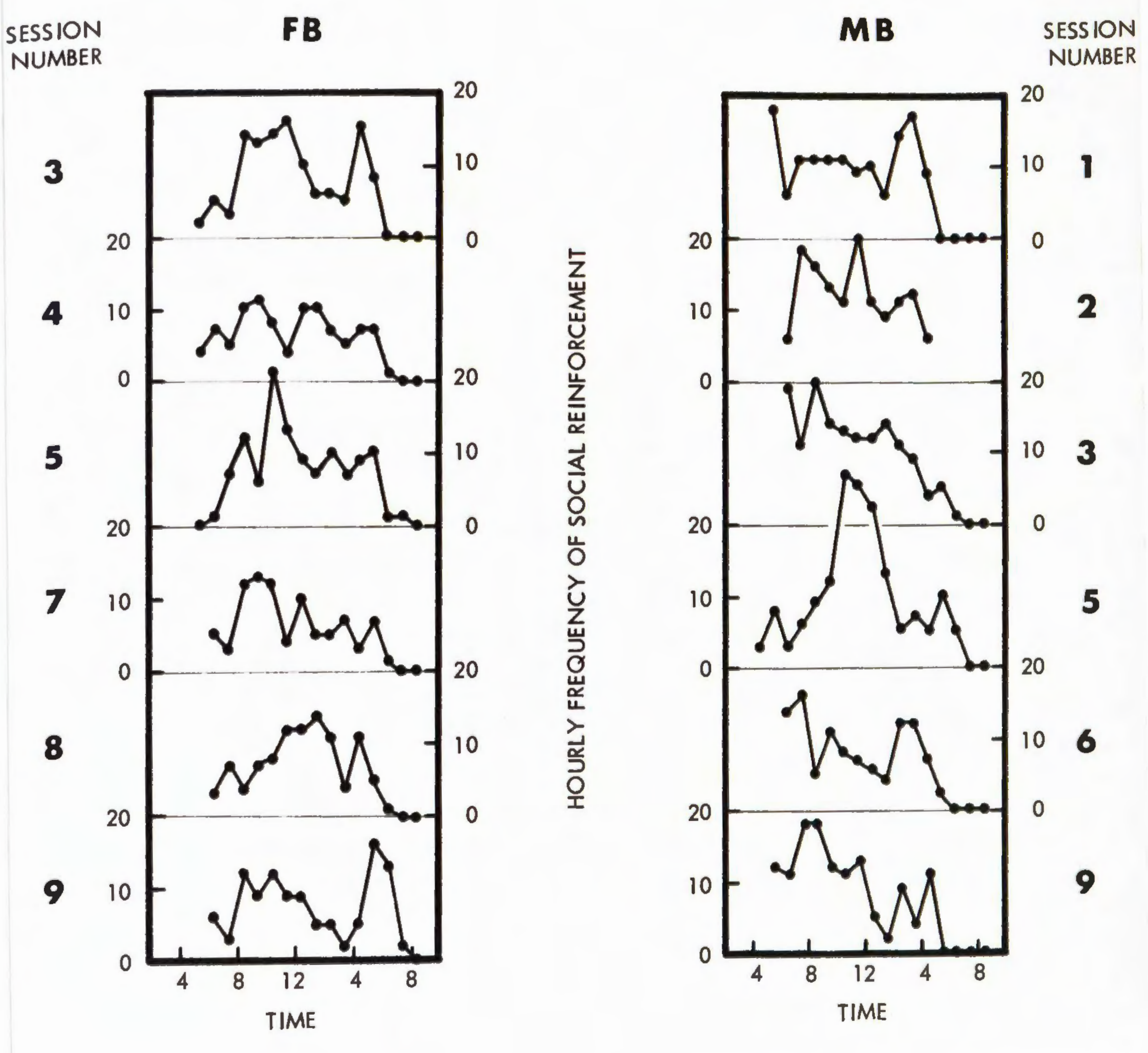

FB
MB
MEDIAN HOURLY FREQUENCY OF SOCIAL REINFORCEMENTS
14
12
10
8
6
4
2
0
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
a.m.
HOUR
p.m.

Fig. 7. Individual daily distributions of frequency of social reinforcement.


SESSION NUMBER
FB
MB
SESSION NUMBER
3
4
5
7
8
9
1
2
3
5
6
9
20
10
0
HOURLY FREQUENCY OF SOCIAL REINFORCEMENT
TIME
4
8
12
4
8

The two-tailed Mann-Whitney U test (Siegel, 1956) was significant ($p < .05$) for the morning high and the afternoon low comparison, and for the morning high, afternoon high comparison, but was not significant for the afternoon low, afternoon high comparison.

Eight of the nine days comprising MB's averaged data also show an afternoon dip with subsequent rise. Six representative days in Fig. 7 illustrate MB's greater variability while supporting the general pattern. The two-tailed randomization test for the difference between morning (6-12 a.m.) and afternoon (12-6 p.m.) frequencies was significant at the $p < .05$ level.

As might be predicted from the one hour phase difference between the two subjects evident in the averaged distributions, Fig. 6, the hour later start times of 6 a.m. may have affected MB more than they did FB. FB's 5 a.m. and 6 a.m. distributions (Fig. 8) remained alike, but MB seemed to begin more abruptly when started at 6 a.m. and the maximum occurred during the second hour rather than during mid-morning. MB's session number 3 (Fig. 7), showing a similar high initial rate, may have been an effect of the preceding two days of social deprivation.

Other behaviors in addition to social behavior followed a diurnal rhythm. Two-term moving averages of food and water consumption, Fig. 9, seemed to follow a pattern roughly similar to the social. Different scales on the ordinate for food and water, and social reinforcement allow an easier comparison of the patterning. MB's food and water and FB's water frequency distributions were displaced about an hour later than the social but ended the same time in the evening. The only significant

Fig. 8. Effect of starting time on shape of the distribution of social reinforcement as a function of time of day.

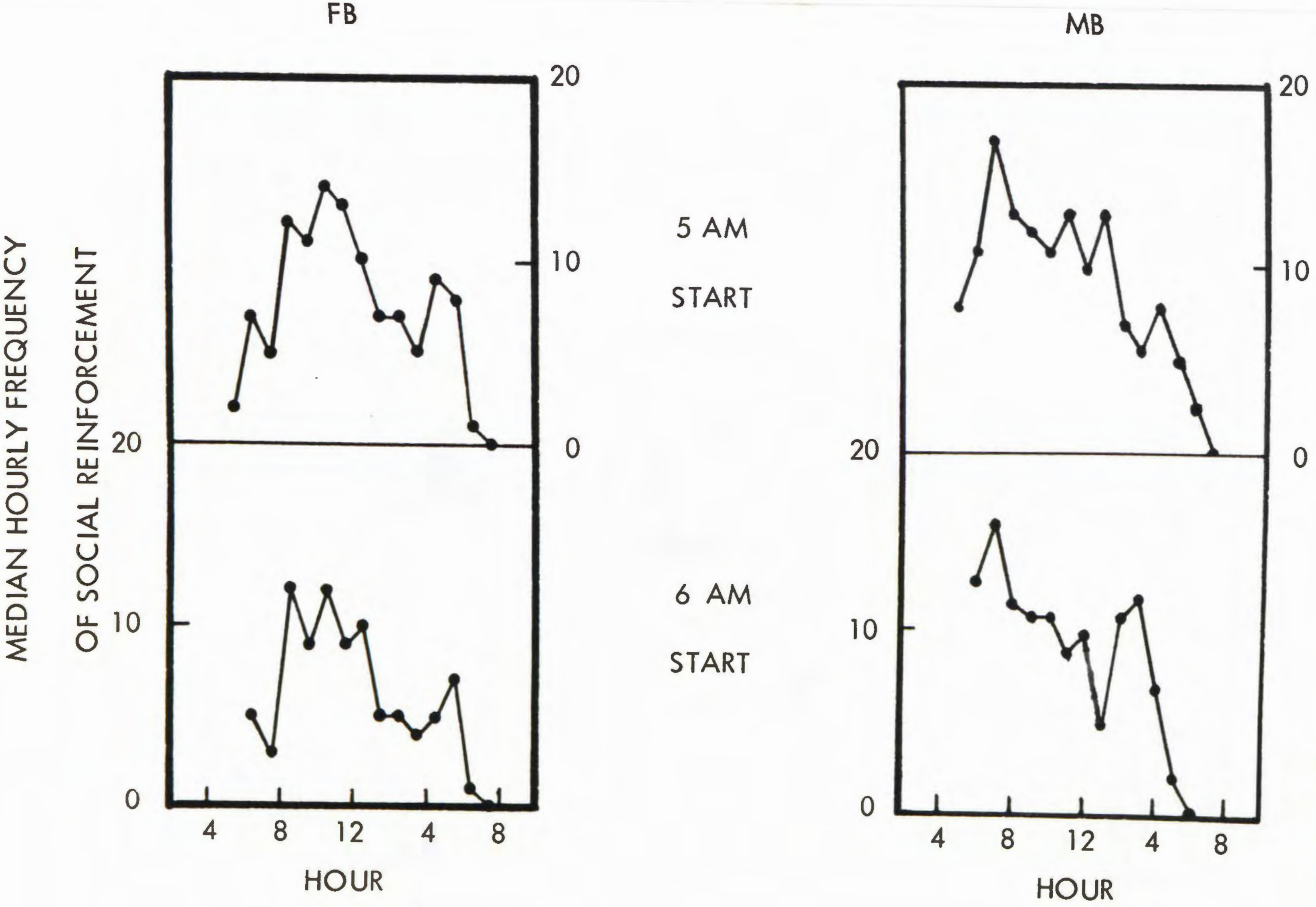
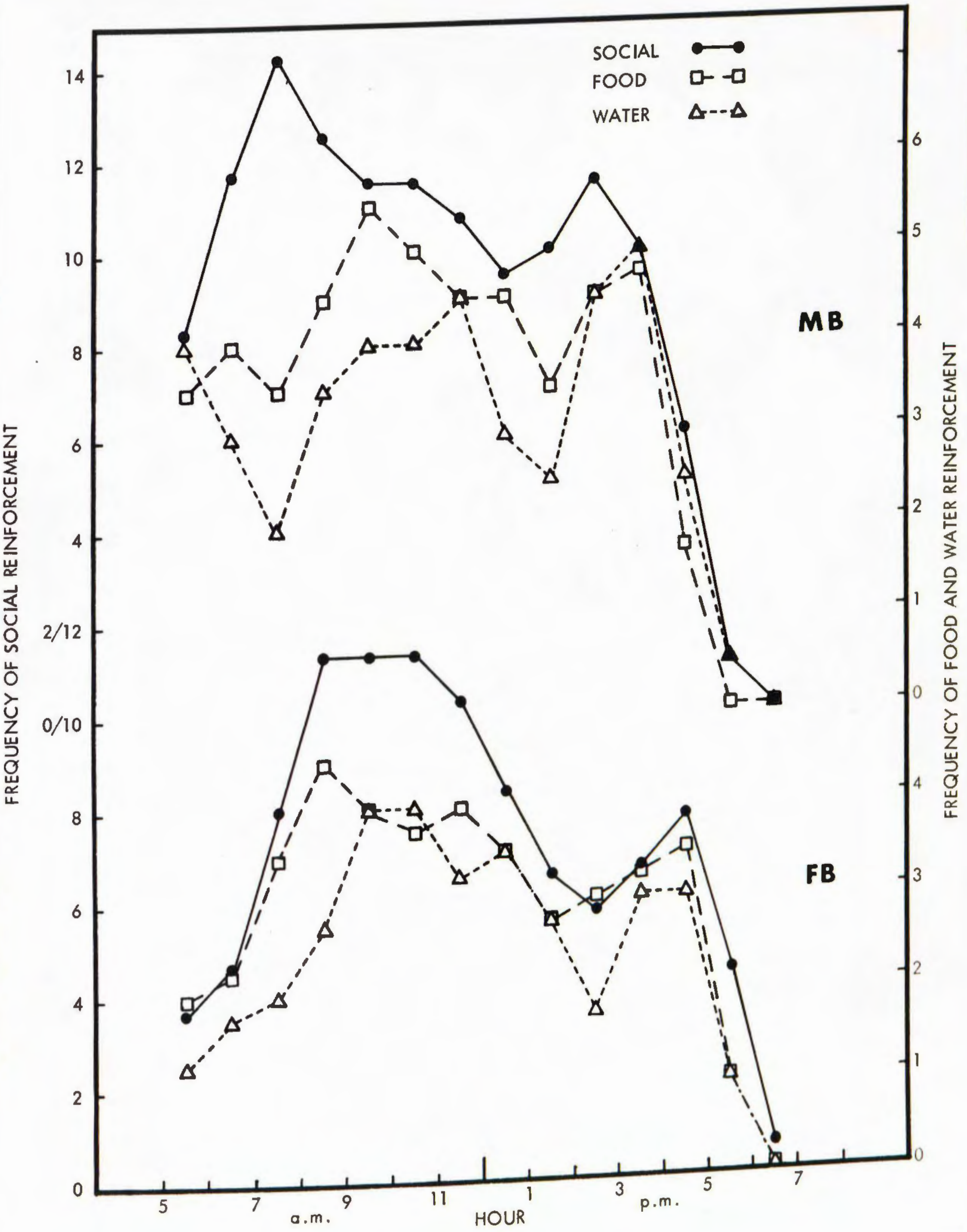

FB
MB
MEDIAN HOURLY FREQUENCY
OF SOCIAL REINFORCEMENT
5 AM
START
6 AM
START
20
10
0
20
10
0
20
10
0
20
10
0
4
8
12
4
8
HOUR
4
8
12
4
8
HOUR

Fig. 9. Distributions of frequency of food, water and social reinforcement as a function of time of day.


SOCIAL ●—●
FOOD □- -□
WATER △---△
MB
FB
FREQUENCY OF SOCIAL REINFORCEMENT
FREQUENCY OF FOOD AND WATER REINFORCEMENT
14
12
10
8
6
4
2/12
0/10
8
6
4
2
0
6
5
4
3
2
1
0
4
3
2
1
0
5
7
9
11
1
3
5
7
a.m.
p.m.
HOUR

differences were in FB's data between the morning peak and afternoon low and between the afternoon low and afternoon peak of water reinforcement ($p < .05$ two-tailed Mann-Whitney U).

No trends could be detected across the time interval encompassed by this experiment. No differences appeared in total number per day of any of the reinforcers, in time of day the baboons ceased responding, or in the timing of the morning or afternoon peaks or afternoon trough.

Discussion

Two principal conclusions emerge from these results. First, the subjects persisted in a 24-hour period circadian rhythm even though not "anchored" by changes in illumination. They obviously continued the 24-hour periodicity instead of dividing their activity up into smaller time periods, alternating with sleep, and spread over more hours. They also showed no tendency towards a period appreciably longer or shorter than 24 hours, but instead remained in synchrony with clock time.

More than 60 years ago Galbraith and Simpson (1903) demonstrated that the sleep and temperature cycles of rhesus monkeys followed reversals of the daily illumination cycle, thus establishing light stimulation as a sufficient condition for phase control of the primate diurnal rhythm. By demonstrating a circadian rhythm without benefit of light changes, the present results allow the conclusion that light cycling is a sufficient but not necessary condition for diurnal rhythms; that the circadian rhythm of monkeys, like that of man can be controlled by other stimuli than light, when light is continuous.

Which stimuli other than light can entrain the endogenous free-running circadian rhythm, or which stimuli are more effective than others has yet to be established. Because the baboons continued in an exact 24-hour cycle despite attempts to provide a "constant" environment, a result at variance with the literature (Aschoff, 1965), several possibilities of "anchoring" will be considered. The ensuing discussion should not be construed as an argument for a precise internal "clock," but rather as an attempt to provide information relevant to an unsettled area of circadian rhythm research.

A prominent feature of diurnal rhythms is their persistence under changed conditions. It might be possible that the 24-hour cycle of activity carried over from previous day-night experience, not having had an opportunity to subside in the 8 days of experiment 1 and 23 days of experiment 2. Several studies are related to this possibility. Humans freed from the normal clock and day-night cycles in polar areas have continued for long periods with a roughly 24-hour rhythm, but the response seems highly individualistic, some quickly adapting to non-24 hour rhythms (Lewis & Masterson, 1957). When rodents and lower organisms are released from photic control, the exact length of a particular individual's intrinsic rhythm and its difference from 24 hours, usually becomes apparent within a week (Cold Spring Harbor Symposium, 1960; Bunning, 1964; Aschoff, 1963). Lindsley, et al, (1962) by exposing two young macaques to a single hour of diffuse illumination each day, successfully entrained their activity. When the time of day of the illumination period was changed, the transition began the first week but the monkeys did not restabilize in the new pattern for three to five weeks. In the present experiment the two observation periods were separated by 30 days and followed more than two months of continuous illumination.

This should have been more than long enough for the effects of previous lighting regimes to subside. In addition, occasional observations indicated that the subjects were already maintaining a strong circadian rhythm prior to the observation period. Although the observations included only a relatively few days, the conditions had been in effect for many weeks. That adjustment to continuous illumination was complete before the observation began, is supported by the subjects' stability from the very first observation day on, and the lack of any systematic trend in the data.

Another factor which might control rhythms in the absence of periodic illumination is temperature. Rhythms are remarkably temperature independent (Sweeney & Hastings, 1960; Rawson, 1960) but few experiments have attempted to control rhythms with cycling temperatures (Cloudsley-Thompson, 1961). One such study varied air temperature from 15° to 25° C in a 24-hour cycle successfully entraining active periods of blinded rats in the cool period (Browman, 1943). However, because of the albino rat's reaction to temperatures in the 25°-30° C range, this result could well have been due to forced suppression of activity during the warm period, much as physical restraint suppresses activity, rather than to a cuing function. The squirrel's activity rhythm was not entrained by 10° C temperature cycling in darkness (DeCoursey, 1960). Ongoing experiments with sparrows have failed to demonstrate temperature entrainment even with a 15° C range (Eskin, 1965). Thus temperature entrainment with homeothermic animals has been often attempted, but only questionably demonstrated once. In consideration of the 10° C or better range encompassed by these experiments and other studies (Aschoff, 1963) the 2° C range encountered in experiment 1 is unlikely to have been either large enough or consistent enough to cue, much less control, activity. However, for half the days of experiment 2 the temperature differential was appreciable, allowing the remote possibility of "anchoring."

An unusual experiment by Halberg, et al (1954), raises the possibility that noise may control activity cycles. Blinded mice demonstrated 24-hour rhythms just as did normal mice in adjacent cages, but when the normals were removed the blinded mice lost their periodicity. Other social stimuli than noise may have been involved. At least one authority asserts that social synchronizers are especially important for animals and humans (Bünning, 1964), but evidence of a positive sort is lacking. In some of Menaker's present work an attempt is being made to entrain sparrows' activity cycles with a variety of sounds, including "social" ones, with no success (Eskin, 1965).

In the present experiments the walls of the cubicle attenuated speech frequencies well, but loud sounds did penetrate, and there were many more such disturbances during the day. However, in order to attribute control of the subjects' rhythmicity to circadian variations in sound levels, the explanatory mechanism has to explain the lack of correspondence between sound levels and times the subjects awoke and slept. They awoke two full hours before the daytime sounds began and slept several hours before they ended at night. Also, the noise pattern was different on weekends, but no accompanying change could be seen in the data.

A final possibility is the restriction of activity by not reinforcing lever responses before 5 or 6 a.m. That it might have affected one subject is suggested by the difference in experiment 2 of the average 5 and 6 a.m. starts of MB in Fig. 8. However, this restriction was not in effect in the first experiment.

Therefore, although the subjects' activity was strongly diurnal with respect to clock time, these experiments allow no definite conclusions as to the causal factors involved, nor were they intended to. They do suggest that the external stimuli synchronizing the subjects' activities may have been more subtle than the literature indicates, and that an extremely well-controlled environment will be necessary to discover them.

The second phenomenon observed was the distinctive morning high, afternoon low, afternoon high patterning of activities throughout the day. The pattern, while most consistent in social reinforcement rate, was also evident in food and water reinforcement rates. Two qualifications must be made. First, the pattern was noticeable only when averaged across several days, not every day showing exactly the same pattern. The lack of statistical significance between most comparisons of the pattern reflects this variability and reduces confidence that the distributions were particularly different from other possible patterns, such as rectangular. Since such a small number of observations requires non-overlapping distributions for significance, more data may have resulted in a different statistical decision.

The second qualification concerns the small number of subjects (two) in this study. However, these observations agree with those made in other situations. Hall (1962) reported that social interactions of chacma baboons in the field were most frequent in the early morning, with a second, smaller rise observed near the end of the day, the exact pattern followed by the two captive baboons of this experiment. Hall and DeVore (1965) report that frequency of copulation followed this same pattern in other troops of baboons. Baboons may differ from other primates, the characteristic primate pattern suggested by field studies consisting of a morning feeding and socializing period, a midday rest period, and a second active period in the afternoon. This pattern has been reported for howling monkeys, red-tailed monkeys, gibbons, chimpanzees, and gorillas (Mason & Riopelle, 1964). Such a species difference coupled with appearance of the phenomena under laboratory conditions grossly different from field studies suggests that rather basic factors influence the patterning.

Under the free conditions of this experiment time of day can be an influential factor governing how many food, water and social reinforcers the baboon will consume. Since consumption varied considerably from morning to afternoon, the difference may also be evident under more restrictive conditions. This possibility is investigated in the following experiment.

CHAPTER IV

DIURNAL RHYTHM AND OVERNIGHT DEPRIVATION

Introduction

The free running periodicity study established the subjects' diurnal patterning of activity and the possibility was discussed that environmental factors, including limiting of social and other activities, may have affected or determined the circadian patterning. A second explanatory concept consistent with the observed daily pattern of socializing is that of deprivation. In the morning, the baboons had been isolated without social contact for several hours, and by 1 p.m. they had had social contact for several hours. The lowered frequency of social reinforcement in the afternoons may thus simply reflect satiation. Consequently, the present chapter compares the effects of overnight social deprivation to no social deprivation, on afternoon social reinforcement frequencies. It also provides evidence on the degree to which time of day may have affected the subjects' reinforcement rates, and relations between food and social reinforcement.

Method

Subjects and Apparatus. The subjects and apparatus are the same as those of the previous experiments. The subjects were housed between sessions in the home cages described before.

Procedure. This procedure immediately followed experiment 1, Chapter III, two days being allowed for adjustment to the changed regime. An FR 10 on the appropriate lever produced 20 pellets, 50 ml of water, or opened the door for 135 seconds. After two days the number of pellets was reduced to 10, and the amount of water to 25 ml. Except for the last condition, sessions lasted four hours, either from approximately 9 a.m. to 1 p.m. or from 1 to 5 p.m. The subjects were exposed to this procedure for two weeks before the experiment proper. Over the next six weeks two levels of food deprivation, two levels of social isolation, and two times of day were produced by alternating subjects morning and afternoon, by conducting only morning or only afternoon sessions, and by pre-feeding and "presocializing" in a sequence designed to contrast the effect of one condition against another. Descriptions of each of the five conditions are followed by a summary in Table V depicting the time of day of sessions for each subject and the sequence and duration of each condition. Degree of deprivation was defined by the length of time since the end of the previous session.

During the Afternoon condition the subjects alternated morning and afternoon sessions. A subject had a morning session one day, an afternoon session the next day, a morning session the next day, and so on. The social contingency was in effect only for the afternoon sessions. Thus the subjects were deprived overnight of all three reinforcers. During the Morning condition the social contingency was in effect only for morning sessions, just the converse of the Afternoon condition.

Under the pre-fed Alternating condition the social contingency was in effect both morning and afternoon sessions and the subjects had free access to food and water while in the passive cage, mornings. This condition provided equal deprivations among reinforcers, overnight for morning sessions and none for afternoon sessions.

Pre-fed Consecutive Afternoon conditions consisted of a morning session followed by an afternoon session, except that the social contingency was in effect only during

Condition:	Afternoon						Morning		Pre-fed Alternating					Pre-fed Consecutive Afternoon										
Early Morning																								
	no social													no social										
Morning	(M	F	M	F	M	F)	M	F	M	F	M	F	M	(			M	F	F	F	F	F	F	F)
Afternoon	F	M	F	M	F	M	(F	M)	F	M	F	M	F	M	M	M	M	F	F	F	F	F	F	F
							no social																	

Time of Day

Consecutive Days

Condition:	Consecutive																			
Early Morning	F	(F)	F	F	F		F	F	F	M	M			M	M	M	M	M	M	M
Morning	F	(F)	F	F	F	F	F	F	F	M	M			M	M	M	M	M	M	M
Afternoon	F	F	F	F	F	F	F	F	F	M	M			M	M	M	M	(M)	M	M

Time of Day

Consecutive Days

Note: F = subject FB; M = subject MB

Table V Sequence and Duration of Conditions the afternoon half. Relative to the other conditions, this condition maximized amount of social deprivation and minimized amount of food deprivation in the afternoon. Subject MB was run for four consecutive days and then FB was run for seven consecutive days. During the first three days of this condition MB was pre-fed in his home cage mornings instead of by a session in the active cage.

The Consecutive condition has already been described in experiment 2, Chapter III. The data will be presented again in a format compatible with the rest of the present chapter. Sessions began at 5-6 a.m. and ended when the subjects quit responding for the day, always before 8 p.m. Considering the morning period from 9 a.m. to 1 p.m., this condition provides a morning session with no social deprivation. Previously, all morning sessions were preceded by overnight social deprivation.

From Table V it can be seen that the Alternating condition allowed eight hours social access per day, the Afternoon and Morning conditions four, and the Consecutive at least twelve.

Results

Table VI presents the mean rate of social reinforcement as a function of the experimental conditions. Figures 10 and 11 show consecutive daily social reinforcement rates for each subject with hours of social deprivation for each condition indicated at the bottom of the figures. Comparisons of morning to afternoon social reinforcement frequencies either in Table VI or in Figs. 10 and 11 illustrate the main effect of this study. Regardless of deprivation of social or other reinforcers, the subjects displayed a higher rate of social reinforcement in the mornings than in the afternoons. Time of day had a greater and more reliable effect on social reinforcement

Session Time	Condition	Mean Rate of Social Reinforcement		Hours of Deprivation	
		MB	FB	Social	Food
Morning	Morning	14.8	17.0	16	16
	Pre-fed Alternating	18.0	13.8	16	16
	Consecutive	12.0	10.6	0	0
Early Morning	Consecutive	10.5	5.3	12	12
Afternoon	Afternoon	8.5	8.5	20	24
	Pre-fed Alternating	8.8	5.3	0	0
	Pre-fed Consecutive Afternoon	7.0	7.8	20	0
	Consecutive	9.2	7.2	0	0

Table VI. Summary of Deprivation Conditions and Social Reinforcements per Hour

Fig. 10. Daily social reinforcement frequency for subject MB. The numbers above the abscissa indicate hours of social deprivation.

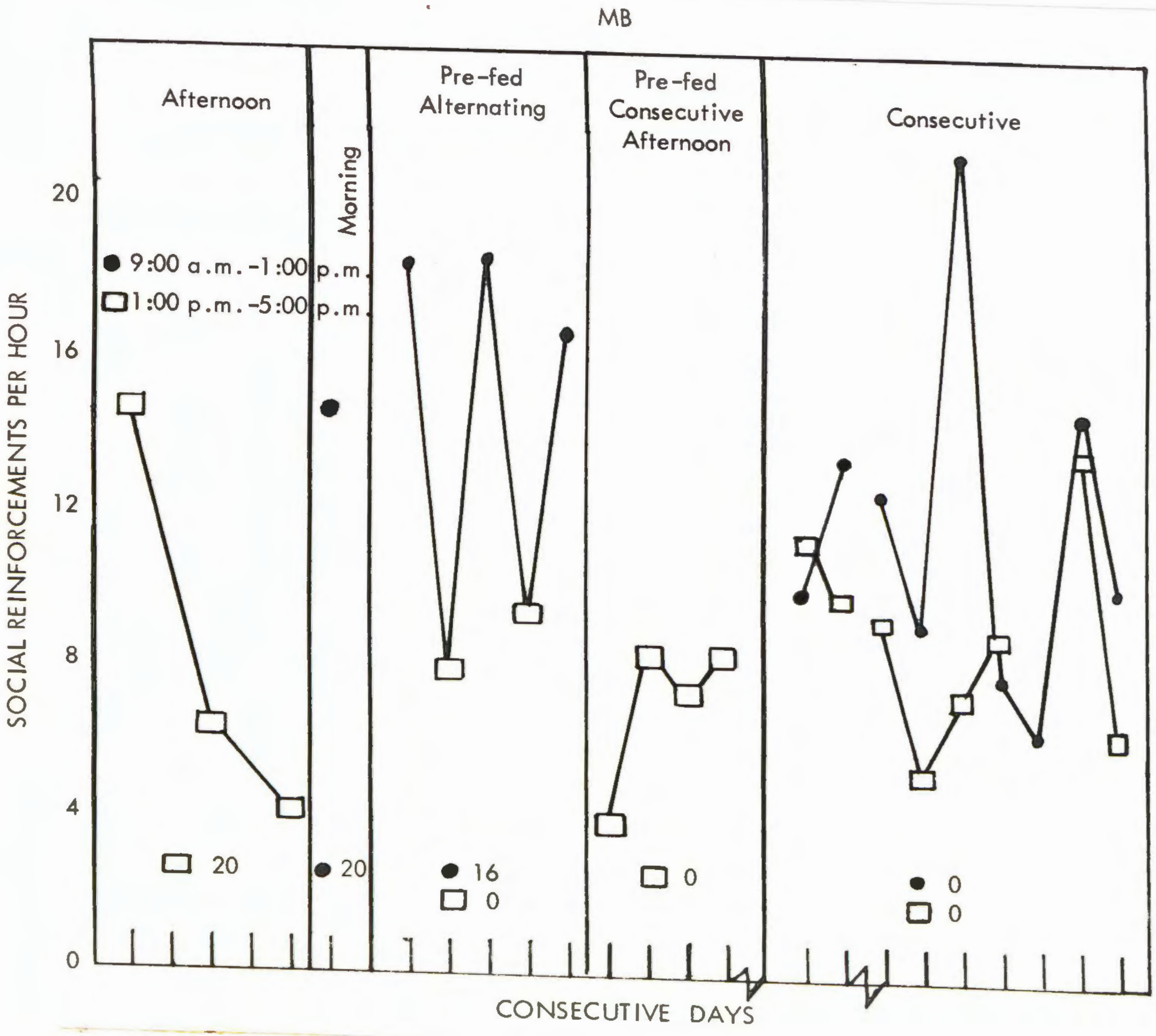
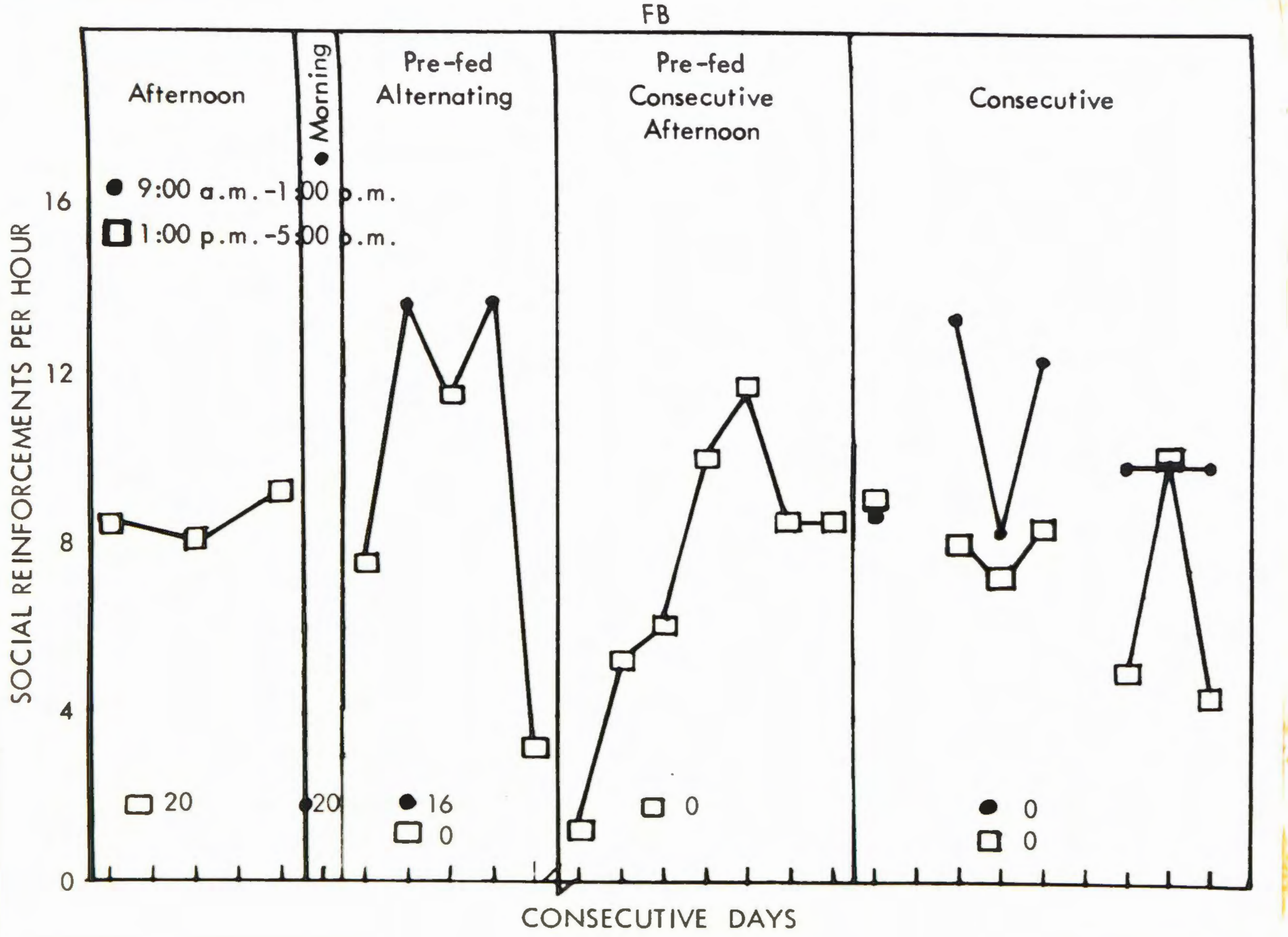

MB
Afternoon
Morning
Pre-fed Alternating
Pre-fed Consecutive Afternoon
Consecutive
● 9:00 a.m.-1:00 p.m.
□ 1:00 p.m.-5:00 p.m.
SOCIAL REINFORCEMENTS PER HOUR
0
4
8
12
16
20
□ 20
● 20
● 16
□ 0
□ 0
● 0
□ 0
CONSECUTIVE DAYS

Fig. 11. Daily social reinforcement frequency for subject FB. The numbers above the abscissa indicate hours of social deprivation.


FB
Afternoon
Morning
Pre-fed Alternating
Pre-fed Consecutive Afternoon
Consecutive
● 9:00 a.m.-1:00 p.m.
☐ 1:00 p.m.-5:00 p.m.
SOCIAL REINFORCEMENTS PER HOUR
0
4
8
12
16
☐ 20
● 20
● 16
☐ 0
☐ 0
● 0
☐ 0
CONSECUTIVE DAYS

rates than did deprivation. The following paragraphs present a more detailed examination of the results.

The Afternoon condition, by having only one social session per day, and that session in the afternoon, produced equal time since last access for all three reinforcers. FB's resulting rates were much more stable than MB's. Both subjects' single session of the Morning condition suggested that their social reinforcement rates were higher in the morning than in the afternoon. In the Pre-fed Alternating condition neither subjects' afternoon social reinforcement frequencies changed, but an appreciable difference was shown between morning and afternoon sessions.

Social deprivation was increased in the Pre-fed Consecutive Afternoon condition by allowing social access for only four hours per day. Food and water were available morning and afternoon, thus maintaining no food deprivation. MB's afternoon social reinforcement rate again continued unchanged, and FB's, after a low beginning, returned to the afternoon rate of the previous Afternoon and Pre-fed Alternating conditions. Each subjects' rates during morning sessions were significantly different from their rates during afternoon sessions ($p < .05$ two-tailed Mann-Whitney U).

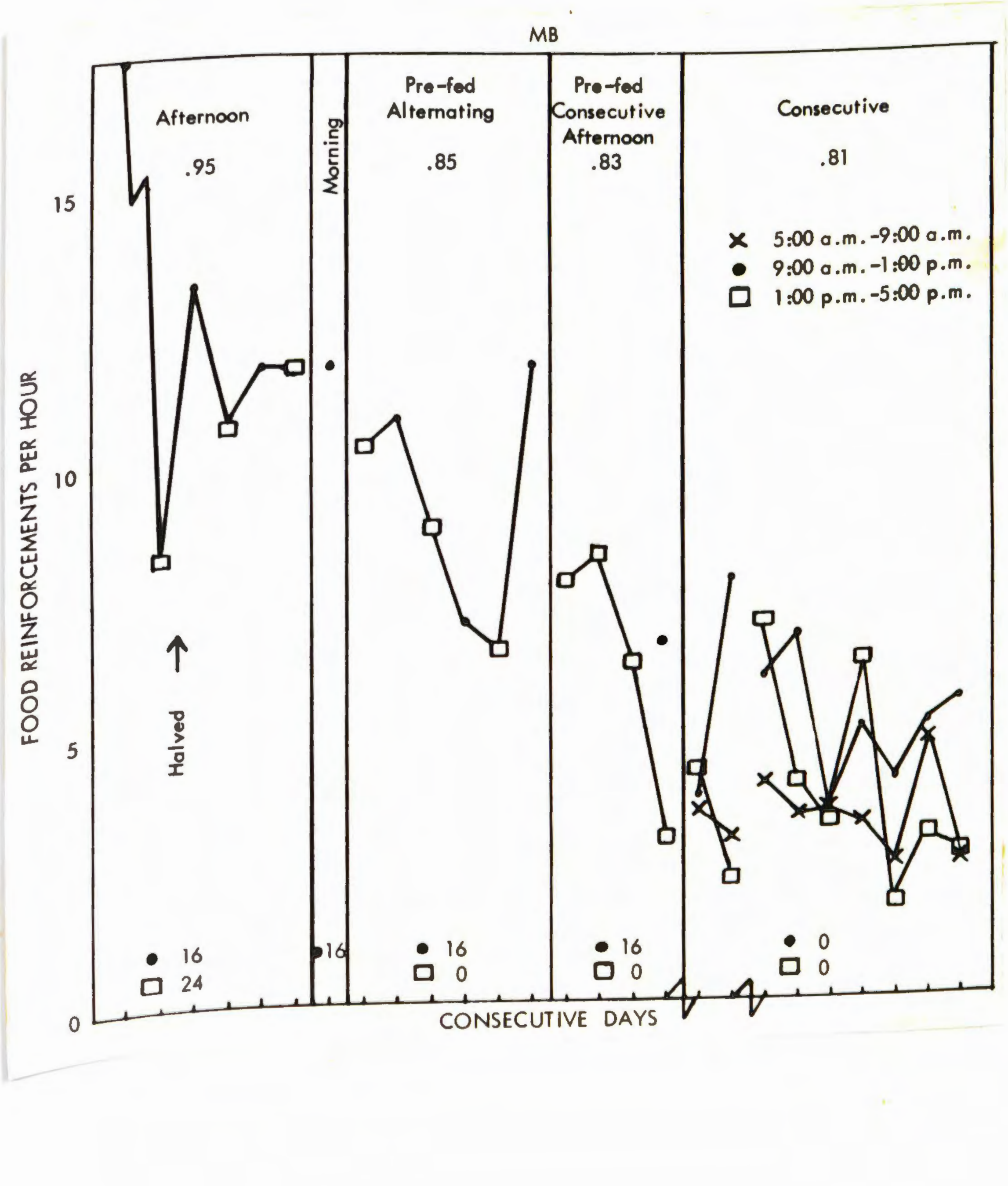
The morning rates during the Consecutive condition were significantly lower than the morning rates during the Morning and Pre-fed Alternating conditions for subject FB ($p < .05$ two-tailed Mann-Whitney U). Despite the eight hours "presocializing" the afternoon rates were no lower than during previous conditions. Afternoon and morning rates, although still significantly different for each subject ($p < .05$ two-tailed randomization test for related samples), were not as separate from each other as in the previous conditions.

Daily food reinforcement rates parallel to social reinforcement rates are shown in Figs. 12 and 13. Numbers at the top of the figures refer to the mean relative frequency of a food or water reinforcer being received while the door was closed, as opposed to open. Finding that more reinforcers were received while the door was closed could be explained by unequal opportunities for reinforcement if the door was closed more than it was open. To adjust for this possible artifact, reinforcement rates were calculated separately for door open and door closed conditions. In order to have a single number reflecting relative frequency, the reinforcement rates were inserted into the formula: $p = \frac{B}{A + B}$, where A is frequency of reinforcement while the door was open, and B is frequency of reinforcement while the door was closed.

MB began receiving more food reinforcements than he ate, and on the first morning of the Afternoon condition, he operated the pellet feeder 1710 times and drained the water system, too. In an attempt to regain reinforcement frequency as an index of eating and drinking, the amount of food and water per reinforcement was halved for both subjects. Subsequently, MB received fewer reinforcements, but he still received more than he ate, as shown by numbers of pellets in the waste pan. Thus MB's food reinforcement rate bore little relation to the experimental conditions.

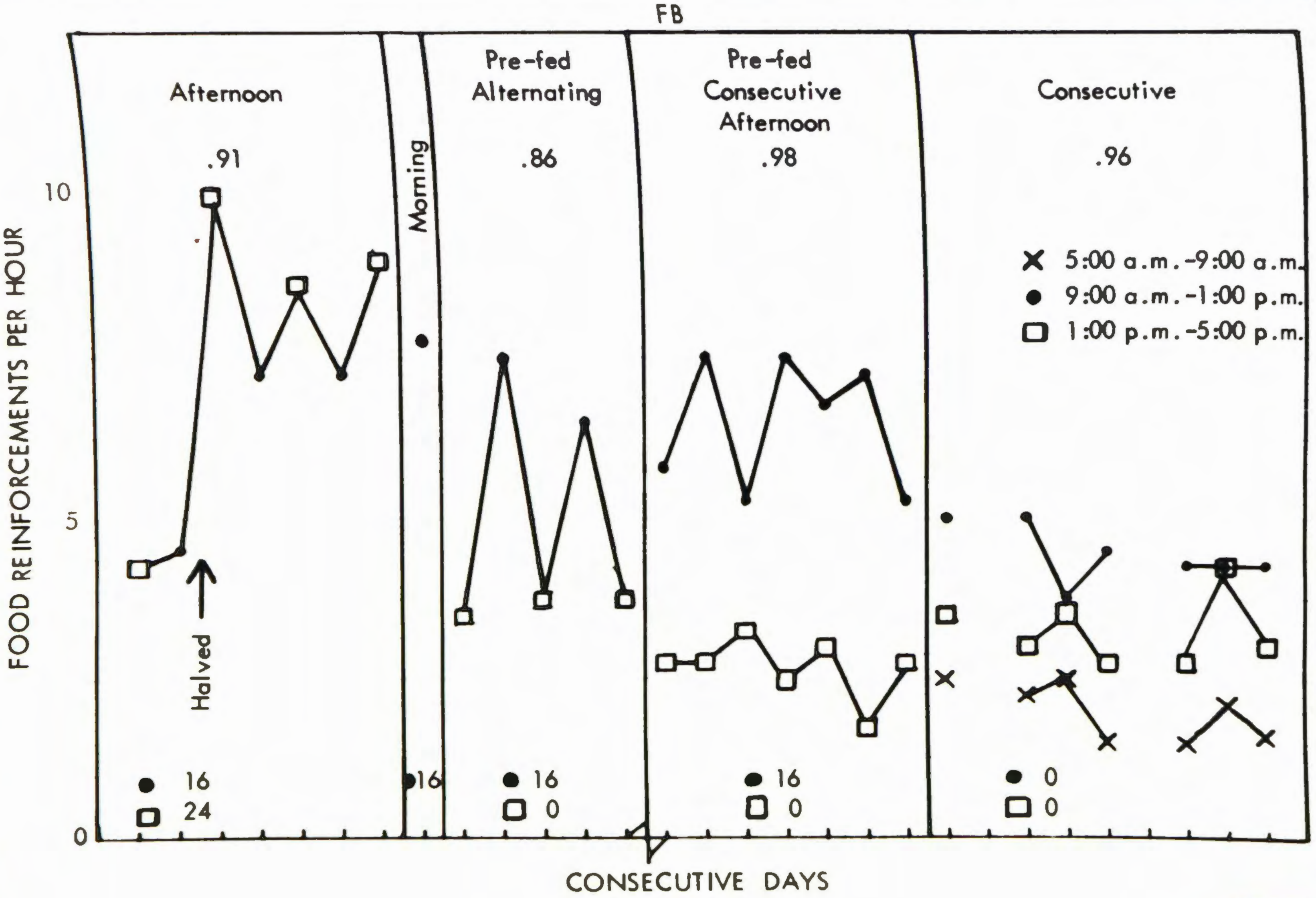
FB's food reinforcement rate appeared closely related to hours of deprivation, as can be seen in Fig. 13. Except for the last condition all morning sessions began 16 hours after previous access to food. The resulting morning rates remained the same across three procedural variations even though two of the conditions doubled the number of hours access to food per day. In the Afternoon condition, when hours of deprivation were greater for afternoon than morning sessions, the afternoon food reinforcement rate was also greater. Under the Consecutive condition a time of day effect

Fig. 12. Daily food reinforcement frequency for subject MB. The numbers above the abscissa indicate hours of food deprivation.



MB
FOOD REINFORCEMENTS PER HOUR
CONSECUTIVE DAYS
0
5
10
15
Afternoon
.95
Halved
Morning
Pre-fed Alternating
.85
Pre-fed Consecutive Afternoon
.83
Consecutive
.81
× 5:00 a.m.-9:00 a.m.
● 9:00 a.m.-1:00 p.m.
□ 1:00 p.m.-5:00 p.m.
● 16
□ 24
● 16
● 16
□ 0
● 16
□ 0
● 0
□ 0

Fig. 13. Daily food reinforcement frequency for subject FB. The numbers above the abscissa indicate hours of food deprivation.


FB
Afternoon
.91
Morning
Pre-fed
Alternating
.86
Pre-fed
Consecutive
Afternoon
.98
Consecutive
.96
✕ 5:00 a.m.-9:00 a.m.
● 9:00 a.m.-1:00 p.m.
□ 1:00 p.m.-5:00 p.m.
Halved
● 16
□ 24
● 16
● 16
□ 0
● 16
□ 0
● 0
□ 0
10
5
0
FOOD REINFORCEMENTS PER HOUR
CONSECUTIVE DAYS

became apparent, perhaps due to essentially no food deprivation during waking hours. The afternoon rate of food reinforcement did not decrease, despite four more hours' access to food per day.

Discussion

The result of principal interest was the consistent difference between morning and afternoon frequencies of social reinforcement. One interpretation is that the afternoon frequencies were lower because the morning session produced a satiated subject for the succeeding afternoon session. If this were so, then during the Afternoon and Pre-fed Consecutive Afternoon conditions, when there were no morning sessions, and the subjects were as deprived as during morning sessions, the afternoon social reinforcement rates should have increased to equal the morning rates. However, the subjects' afternoon rates showed no indication of an increase as a result of overnight social deprivation. This result removed satiation as an explanation for their lower afternoon rates in the Pre-fed Alternating condition or in the free-running conditions of the previous chapter. The deprivation/satiation operation failed to produce deprivation/satiation phenomena in either subjects' afternoon social reinforcement rates.

A related interpretation of the free-running pattern directs emphasis to the mornings: the higher morning rates were the result of greater deprivation. If this were so, then the free-running pattern should have begun high and gradually decreased, rather than, as actually occurred, beginning low and increasing. Therefore this interpretation cannot explain both the low early morning rates and the middle morning high rates.

If the same interpretation applies to the limited session duration conditions, then an early morning session before the morning session should decrease the degree of social deprivation, and therefore the reinforcement rates. For both subjects there appears to be less separation between morning and afternoon rates in the free-running condition with the early morning session, and the morning rates in this condition were lower (significantly so for FB) than the morning rates of the other conditions. Thus "pre-socializing" may have produced the satiation phenomena in both subjects' morning social reinforcement rates. This conclusion is tentative, however, since an alternative explanation, a time effect, is not excluded by the design of the experiment. The morning social reinforcement rates being lower during the Consecutive condition than during previous conditions could have been associated only with the lapse of time.

Therefore, the social deprivation/satiation operation may have had an effect, but only in the morning at the height of social activity and not in the afternoon. Social deprivation may have greater effects under other conditions, perhaps over longer time spans or when social reinforcement only totals to minutes instead of hours per day, but under the conditions of this experiment, the effects of deprivation were secondary. The last result suggests the possibility that social deprivation had an effect, but that the diurnal rhythm must be considered.

This finding appears related to circadian rhythms in susceptibility to various agents. Systematically fluctuating susceptibility to endotoxins (Halberg, 1960), audiogenic seizure (Halberg, et al, 1960), X-irradiation (Pizzarello, et al, 1964), Nembutal (Emlen, 1963) and immobilization (Ader, 1964) has been documented with rodents as being closely related to time of day. Definition of the stage of the circadian rhythm is particularly critical when an effect is detectable at only one point in the rhythm, as was the effect of the social deprivation/satiation operation of this experiment.

The detection of differences in 0, 16, and 24 hours of food deprivation by the food reinforcement rate provides some assurance that the measure was a suitable one. Finding that the measure discriminated the effect of time of day reliably, lessens the probability that the invariance of afternoon social reinforcement rate to deprivation was due to an insensitive technique.

Social reinforcement rates did not reflect variations in food deprivation as would be expected if food reinforcement or eating behaviors were facilitating or inhibiting social behaviors. Additionally, since food reinforcement rates varied with food deprivation, increasing and decreasing numbers of food pellets also did not affect the social reinforcement rate. The very high probabilities of food reinforcement occurring only with the door closed, essentially invariant across various experimental conditions, shows that rather than being completely independent of each other, food and social reinforcement rates tended to be mutually exclusive, perhaps even incompatible. Taken together these results imply that the presence of food did not appreciably affect the subjects' social reinforcement rates.

CHAPTER V

GENERAL DISCUSSION

It is important to establish to what degree the reinforcing stimuli were social in a full sense of the word. The artificial, highly restricted experimental conditions undoubtedly limited a full display of the monkeys' social behaviors. For instance, the complete expression of mounting, a very common form of interaction in larger enclosures, was prevented by the bars separating the cages and by the low ceiling. A second "unnatural" feature, foreign to most experimentation in this area, is the automatic recording of social encounters. In nearly all previous research the observing experimenter has been an integral ingredient.

There is a second reason to establish the reinforcer as principally social in nature. In several previous experiments having primates as the reinforcing objects, the authors arbitrarily described the "motive" as a visual exploration one (Butler, 1957; Moon, 1961). In subsequent experiments having slides as the reinforcing stimuli, the authors also called this "visual attention" and identified an essential feature as stimulus change (Butler, 1963; Symmes, 1963). What assurance is there that the reinforcing monkey served as anything more than an arbitrary complex moving stimulus which could have been substituted for equally well by any display providing a sufficiently varied visual, auditory, and tactual stimulation?

Assurance comes first from the comparison of reinforcement rates with and without a reinforcing monkey on the other side of the door. This also established that the non-social stimulation incidental to presenting the social reinforcer and the restricted cage size would maintain relatively little behavior. Assurance comes secondly from the long and repeated periods of exposure to the social reinforcer. Four to eight hours' exposure a day for several weeks normally results in habituation to even richly changing stimulation, if it doesn't mimic social stimulation (Fox, 1962; Symmes, 1963; Welker, 1956a,b,c,; Wendt, et al, 1963). Both baboons responded as readily after several months of social experiments as they did in the beginning. Additional assurance comes from the baboons apparent preference for their own species. After MB, FB and MM had become thoroughly familiarized with each other, the two baboons opened the door to MM, the Mangabey, much less than they did to each other. MM, a different species, may have exhibited some reactions inappropriate to baboons.

A short description of a typical social interaction between the monkeys also bolsters credence in the interpretation of the reinforcing stimuli as peculiarly social. MB was most receptive to being groomed, MB, in Fig. 14 displays a typical distant expression while being groomed, while FB brushes through his neck hair. FB, however, greatly preferred vigorous play (Fig. 15). These differing tendencies were not always compatible. A familiar sequence observed was for FB to bite MB at first lightly and then harder, to pull easily a few times and then yank. This would often provoke MB to react in kind resulting in continuing play. Occasionally, however, MB would scream, apparently injured, and when the door closed he would leave it closed while engaging in various self-directed activities, primarily self-grooming. A good impression of the intensity with which the baboons played may be gleaned from Fig. 15, a typical posturing. Thus there is little doubt that the social reinforcer was both reinforcing and social, but it still may have gained additional

Fig. 14. FB grooming MB.

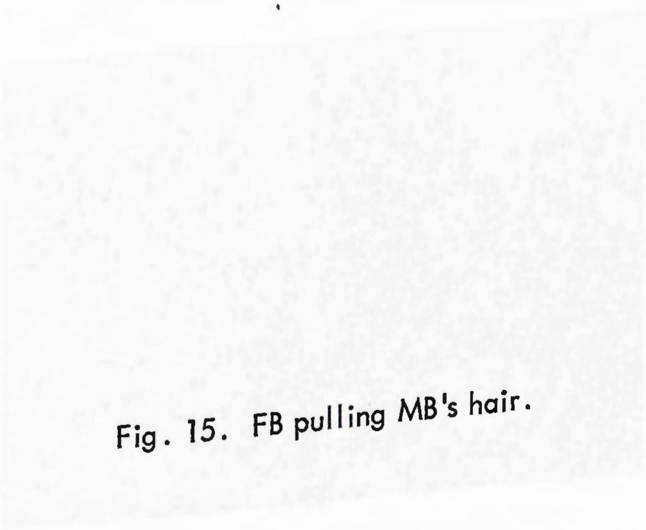


Fig. 15. FB pulling MB's hair.

strength from a complexity or stimulus change effect. In the delineation of the specific and essential characteristics of various social reinforcers, this sort of emphasis may prove valuable, but at our present state of knowledge it certainly seems possible that complexity may be intrinsic to effective social reinforcement. The present study at least does not omit a component which may ultimately prove important to the understanding of social reinforcement. The problem is an experimental one and the answers should be sought experimentally.

A closely related problem concerns the relation between the concept of general activity and social activity. Since previous research has so thoroughly documented the relation between circadian rhythms and general activity (Cloudsley-Thompson, 1961), the question arises as to whether the measures used in this experiment were tapping socialization tendencies exclusively, or whether they were augmented by a less specific, general tendency towards movement. One type of incidental augmentation can be eliminated. As was mentioned in the initial procedures section, the monkeys discriminated the functions of the three levers well, particularly after having several months' training in the apparatus. They frequently made anticipatory gestures to the reinforcement dispenser due to be activated by completion of the ratio requirement, thus further indicating that they seldom responded "accidentally." There were also two non-functional levers a few inches above the others. These were depressed only 2-3 times/week, and usually then in the process of picking at cracks, bolt heads and similar structural irregularities in the cage. Observations also revealed that bar pressing was not a component in any stereotyped cage behavior.

The appropriateness and desirability of a concept of general activity as well as whether it is a unitary concept has been cogently doubted for several years (Slonaker, 1912; Reed, 1947). The trend has been toward description of specific behaviors (Cofer & Appley, 1964). However, agreement is far from complete, particularly since the introduction of the concept of the reticular activating system (Magoun, 1958) and level of arousal (Lindsley, 1957). Bindra (1961) has renewed the proposition with a response competition approach and at least one investigator reports substantial agreement between automatic devices and human raters' indices of general activity (Isaacs, 1956). Adey (1965) has recently demonstrated equivalence of objective behavioral and computer analized EEG definitions at several levels of arousal. The only authority on primate social behavior to comment on the topic has tentatively identified preference for different social activities with changes in arousal level but not with social and non-social activities (Mason, 1964), thus suggesting that the method of social reinforcement in the present experiments was to some degree independent of "general activity."

A social object is not just like a food object, but despite striking differences between them, the concept of reinforcement can be productively applied to both. However, social reinforcement did differ from food reinforcement in some respects. It was less reliable and predictable, at times even erratic. Occasionally, in earlier pilot work, a monkey would nearly stop responding for several hours or even days, only to spontaneously begin again. Other times substituting food or a different monkey as the reinforcer, or forcing long extended periods of contact appeared to stimulate a recovery. The most probable unitary explanation for a major portion of this variability concerns the actual content of the interactions between the monkeys. On three known occasions the "reinforcing" monkey strongly punished the monkey controlling the door, leading to low or zero door opening rates for varying periods of time. Once, FB held MM's penis as the door descended, forcing it to be pinched by the door. In a second incident, an adult male, after repeated unsuccessful attempts to mount a female in estrus, bit her swollen rump, causing bleeding. In a third incident the door closed on, pinched, and held the adult male's foot. The female immediately reopened the door and the male attacked her viciously. Only by a long, careful retraining process was it possible to induce her to open the door again. These opportune observations point out one possible explanation for the periods of asocial behavior. Undoubtedly, there were other variables involved.

Because of the strong diurnal rhythm effect it may appear that social tendencies were not affected by isolation in the same manner that deprivation affects eating. However, the diurnal rhythm effect is probably one of degree, not of kind. Bare (1959) and Bare and Cicala (1960) found the same phenomena to a lesser degree in the amount of food eaten by rats following a single deprivation. They concluded that the rate at which the animal eats is determined largely by the time of day at which the measures are obtained, even after deprivation. The time-of-testing variable not only predicts the rate of intake after the first hour of eating, but may be counteracting the effects of the deprivation variable during the first hour.

The several reviews of pertinent literature concur that stimulus change, novelty, and exploration experiments feature habituation and deprivation phenomena (Berlyne, 1960; Bindra, 1959; Glanzer, 1953; Thompson & Spencer, 1966). Thompson & Spencer state, "Examples of response habituation can probably be found in essentially all behavioral studies where a stimulus is regularly presented." (underline theirs). This statement appears in agreement with the facts as long as specific, physical, formal meanings of the word stimulus are followed. However, the authors include an experiment (Butler & Harlow, 1954) in which the reinforcer was an object, a monkey, not a specific stimulus, and in which persistence, not habituation, was demonstrated. There is a clear demarcation between studies using various forms of novel reinforcing stimuli which show habituation (Thompson & Spencer, 1966), and studies using primates as subjects and as reinforcing objects which show persistence (Butler, 1957; Butler & Alexander, 1955; Butler & Harlow, 1954; Moon, 1961; the present study). Because of this it is probably inappropriate to combine studies using monkeys as reinforcers with studies using slides as reinforcers under the common rubric, "visual exploration."

The special effect of deprivation on this form of social reinforcement also suggests that the stimuli supplied by one monkey to another have enough variety to nullify specific habituations; that the concept of stimulus treated as generic may be less subject to habituation. In the present experiment a deprivation effect appeared only at a certain time in the day and its magnitude was smaller than the effect of the diurnal rhythm. Butler (1957) isolated monkeys in the chamber for periods ranging from zero to eight hours, which resulted in only a 20% difference between zero and four hours, and no further increase beyond four hours. Another experiment by the same investigator (Butler & Alexander, 1955) failed to show any satiation either within ten-hour sessions or across six days. This could be interpreted to mean that the former result was more due to isolation than to deprivation.

Increased effectiveness of social reinforcement after short periods of social deprivation analogous to the effects of food deprivation were reported with children (Gewirtz & Baer, 1958). This effect occurred with either of two systems of social deprivation, a few minutes' isolation in a separate room, or unresponsiveness of the adult reinforcer, thus raising an interesting possibility concerning actual levels of social deprivation in the baboons. Definition of degree of social deprivation in terms of hours since last opportunity for contact, is operationally equable to the isolation of the child in the Gewirtz and Baer studies. However, there was no direct way to control the other type of social deprivation, an unresponsive reinforcer. That this condition probably did occur was mentioned earlier in the discussion on content of the reinforcer. Another possible source of unaccounted variability inevitable when social deprivation is defined in this way results from not discriminating which subject could control and open the door. The subject was classified as having zero hours social deprivation if a session was just concluded regardless of whether he had been in the active or passive cage. If in the passive cage, he had also been deprived of responding on the manipulanda in the active cage, and this response, or manipulanda, deprivation could have increased the tendency to respond (Premack, 1963). However if this possibility was having an appreciable effect, it should have been shown in differences between the one-session-per-day conditions and the alternating two-sessions-per-day conditions.

Whether or not the subject controls the door could conceivably affect the content and therefore the relative degree of the social reinforcer, especially in view of Kavanau's (1964) finding that several stimuli can function as either negative or positive reinforcers depending upon whether the organism controls their presentation or just their termination. None of these possible contaminating factors appear to have great explanatory power since they would work contrary to the results and to the circadian rhythm effect, increasing rates of social reinforcement for sessions later in the day.

These studies have established social reinforcement under controlled laboratory conditions as a strong reinforcer capable of maintaining behavior over long periods of time. That organisms being so extremely mutually interdependent for survival in the wild are also strongly social in the laboratory should be expected. Even the finding that social tendencies may vary according to time of day has the obvious evolutionary significance of keeping the baboon troop together. However, the generality of these results are sharply limited, only two individuals of one sub-species being closely examined. A closely related species, man, often called the social animal, typically has quite idiosyncratic patterns of social activity.

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