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THE EFFECT OF FOOD DEPRIVATION ON VISUAL RESPONDING IN HUMANS

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ABSTRACT

Previous research indicates that a 14 hour food deprivation can significantly increase visual sensitivity as measured by absolute threshold and the effect of an inducing annulus on the brightness of a test field. The present study was designed to extend food deprivation time to 72 hours and include a number of physiological measures, along with visual sensitivity, as a function of deprivation time. A complete replication of the deprivation schedule was included to determine adaptation of both visual and physiological responses to food deprivation.

Two groups of five subjects each were formed by random assignment from a group of ten male college students who had been judged medically fit to withstand the stress of the food deprivation schedule. One subject was eliminated from the Experimental group midway through the experiment because of illness. The Control group received a highly controlled maintenance diet of 2200 calories/day throughout the 22 day course of the experiment. The Experimental group, on the other hand, was fed on the following schedule: five days of maintenance diet, 72 hours of complete food deprivation, six days of maintenance diet, 72 hours of complete food deprivation, and five days of maintenance diet. With the exception of days 12 and 13, experimental sessions were held twice a day. In all sessions, three visual measures were taken using the method of adjustment: (a) absolute threshold, (b) the brightness of a test field surrounded by a dimmer inducing annulus (enhancement), and (c) the brightness of a test field surrounded by a brighter inducing annulus (inhibition). Following each visual session, measures were taken of oral temperature, blood pressure, pulse rate and subjective ratings of hunger and fatigue. Additional measures on the same subjects included body weight, blood serum

glucose and sodium levels, sodium and potassium excretion from the urine, and blood pressure and heart rate measured before, after and following recovery from five minutes of strenuous exercise.

On each of the above measures subjects were equated statistically on the basis of predeprivation response levels. Group means calculated from the above values provided a measure of the mean amount of change across the feeding and deprivation schedule. The results of the visual measures showed significant group differences on threshold and inhibition change but not on enhancement change. The point at which the difference occurred, however, and the direction of the difference were completely unexpected. Both groups showed threshold decreases during the initial predeprivation period which continued through the first deprivation period. The point of separation of the groups occurred with the resumption of feeding of the Experimental group where their threshold level increased to the initial predeprivation level and remained relatively stable through the second deprivation and recovery periods. The Control group, after its initial decrease in threshold, remained at a low threshold level throughout the remainder of the experiment. The inhibition results are similar to the threshold results. The physiological results showed changes consistent with the feeding and deprivation schedule. Oral temperature, systolic blood pressure, serum glucose and sodium levels, and urine sodium and potassium excretion decreased with hours of deprivation while diastolic blood pressure and activity state pulse rate increased. The Experimental group showed significant increases in ratings of hunger and fatigue in both deprivation periods.

It was concluded that (a) the conditions of the present study resulted in significant differences in visual responding between food deprived and nondeprived groups; (b) the nature of the changes in visual responding, which are only partly accounted for by hours of food deprivation, suggest the presence of other variables of a more psychological nature; and (c) the visual changes are not directly related to changes in autonomic responding or to subjective ratings of hunger and fatigue.

Possible reasons for the unpredicted changes in visual responding were discussed.

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CHAPTER I

In visual research, the initial task of the investigator is the determination of functional relationships between physical properties of a light stimulus and the resulting behavioral responses. When these relationships have been determined to the highest possible degree of accuracy, however, a large source of variance remains which cannot be accounted for by changes in the light stimulus. For example, an individual's absolute threshold to light will vary from day to day and even from response to response within a session. In order to understand the sources of this variance, the investigator might then attempt to isolate aspects of the total stimulus situation, other than the light, which are contributing to the response variability.

An example of such investigation is found in a series of studies by Diamond (1953, 1955, 1960, 1962a, 1962b) in which the effects of luminance, area and separation between fields were determined. Equations employing these three stimulus terms were developed to account for the brightness response in the dark adapted fovea to both single and multiple field stimuli (Diamond, 1960). Subsequent research in Diamond's laboratory on variables other than the light stimulus showed that visual sensitivity increased with caffeine intake (Kleman, Diamond and Smith, 1961), at ovulation during the menstrual cycle and with hours of food deprivation.

The present research is an extension of the above approach, that is, its main purpose is to determine the effects of a non-light-stimulus variable, long term food deprivation, on measures of visual sensitivity. However, on the basis of practical and theoretical considerations discussed below, it has as ancillary purposes the determination of the effects of food deprivation on physiological responses, and adaptation to food deprivation through successive deprivation periods.

Food deprivation and visual perception

Studies of the effects of food deprivation on human visual responding are few, and the outcomes are somewhat inconclusive. Benedict (1915) took visual acuity measures on an individual who undertook self-imposed fasts for religious purposes. Over a thirty-three day period of complete food deprivation, visual acuity was found to improve. Kravkov and Semenovskya (1936a, 1936b), on the other hand, found no change in visual acuity for one S during a fifty day period of complete food deprivation which was undertaken as a disease cure, nor for a second S after forty-four days of deprivation. They report, however, a reduced sensitivity to light as measured by the dark adaptation curve. Among the better controlled studies, the most extensive are the Minnesota studies, the results of which are contained in the two volume work entitled Human Starvation (Keys, Brozek, Henshel, Mickelsen, and Taylor, 1950). Thirty-six S's who underwent a twenty-four week period of partial food deprivation which maintained them at seventy-five per cent of their normal weight showed no change in visual acuity at the end of the period. In the Carnegie study (cited in Keys, et al., 1950, p. 58) improvement was found in visual acuity after eight weeks on a diet which maintained 12 Ss at 90 per cent of their normal body weight. Franklin, Brozek, Guetzkow, and Keys (1947) found no change in visual acuity or critical fusion frequency after twelve weeks of partial deprivation. A Buddhist priest deprived of both food and water for nine days showed an increase in visual acuity (Murao, 1960). Diamond, as mentioned above, found increased sensitivity after a six hour period of food deprivation and then decreased sensitivity at 12 to 14 hours.

Despite the lack of consistency in the above results there appears to be some evidence that changes in visual sensitivity occur with food deprivation. The inconsistency might, in part, be due to the fact that (a) measures were not taken during the course of food deprivation days but at the end of periods which differed in length for various studies, (b) different schedules of deprivation were used, that is, two of the studies used partial food deprivation, three used complete deprivation and one used both food and water deprivation, and (c) different measures of visual sensitivity were used in the various studies.

Regarding the first point, if the sensitivity function is other than monotonic, e.g., an inverted U function as suggested by Malmo (1959), then sampling various points along the hours of deprivation dimension would be expected to yield apparent inconsistencies. Diamond, in fact, found that the lowest point in the threshold curve occurred at 6 hours deprivation (0.34 log mL change as compared to zero hours deprivation) then increased up to the 14 hour deprivation point (0.17 log mL change). Thus, it would seem advisable to sample as many points as possible along the hours of deprivation continuum. As to the choice of deprivation schedule, there are certain advantages to using complete rather than partial food deprivation. First, in terms of time and effort, the extremes of hunger can be attained more rapidly with complete deprivation and secondly, the problem of which nutritional components to include in a partial deprivation diet are avoided. Granted that the effects of food deprivation on internal states as well as on behavioral measures probably differ depending on the schedule of deprivation, the simpler schedule is to be preferred where experimentation is still in the exploratory stage.

On the basis of the above considerations, and as an extension of Diamond's investigations, threshold and brightness contrast measures were taken during two 72 hour periods of complete food deprivation. Threshold is defined as the minimal amount of light that can be detected 50 per cent of the time as determined by the method of adjustment (Guilford, 1954). Simultaneous brightness contrast refers to the change which can occur in the subjective brightness of a retinal patch of light of constant luminance, called the test-field (t-field), when a second field of light, called the inducing field (i-field), is focused on an adjacent or surrounding retinal area. Brightness of the t-field was found to be judged as less bright (inhibited) when the i-field luminance was equal to or greater than the t-field luminance (Diamond, 1953; Heinemann, 1955; Klemann et al., 1961), and enhanced when the i-field luminance was less than t-field luminance (Heinemann, 1955; Kleman, et al., 1961). Also, inhibition of the t-field brightness was found to increase with a decrease in separation between t-field and i-field (Beitel, 1936; Fry and Alpern, 1953; Leibowitz, Mote, and Thurlow, 1953), and increase as the area of the i-field increases (Diamond, 1955). In the present study, luminance, area and separation values were chosen so as to maximize the production of inhibition and enhancement. The rationale for treating threshold, enhancement and inhibition as related measures is based on Diamond's findings that as time of food deprivation was increased up to 6 hours, threshold decreased (increased sensitivity), and contrast brightness of the t-field decreased for both the enhancement and inhibition conditions. In addition, it has been found that the administration of caffeine also results in decreased threshold (Smith, 1962) and decreased t-field brightness under enhancement and inhibition conditions (Kleman, et al., 1961).

Food deprivation and internal states

While the main purpose of the present study was the determination of relationships between hours of food deprivation and visual responding, there are reasons for investigating possible relationships between physiological changes which accompany deprivation and concomitant changes in visual responding. Past research indicates that the level of visual response might be correlated with one or more physiological states. Research cited in the preceding section in which changes in visual responding were found to accompany food deprivation provide indirect support for such relationships since marked changes in physiological states were also found. The number of visual measures taken, however, were not sufficient to permit extensive comparisons. In studies using nondeprived Ss, Diamond (1960) found a low but significant correlation between blood pressure and enhancement matching, while Wertheimer (1955) found a similar correlation between normal diurnal variations in temperature and visual threshold. Physiological responses associated with food deprivation can also be manipulated by means other than depriving operations. It was found that lowered blood glucose levels, which were induced by injections of insulin, were accompanied by increased visual thresholds (McFarland & Forbes, 1940; McFarland, Halperin, & Niven, 1945). While McFarland's results support the notion of a relationship between internal states and visual responding, the direction of the effect is opposite to that which is suggested by studies in which blood glucose levels were lowered by means of food deprivation.

In addition to the empirical evidence suggestive of relationships between internal states and visual response level, Malmo (1958) has pointed out the usefulness of discovering their precise form. From a review of the literature on sleep deprivation, and water deprivation, as well as food deprivation, Malmo concludes that specification of the antecedent defining operations alone (i.e. hours of deprivation) does not provide adequate prediction of consequent behaviors (e.g. visual response). One would also need to know the organism's past history with deprivation as well as other uncontrolled antecedent conditions which might effect behavior. Malmo suggests that measures of the organism's internal state might provide a better predictor of behavior since they would theoretically at least, offer the possibility of measuring the combined effects of all the various antecedent conditions which determine a response.

On the basis of the above reasons, the present study includes a number of physiological and biochemical measures that should show predictable changes with food deprivation in an exploratory attempt to relate internal states to visual responding.

Adaptation to food deprivation effects

The last point of interest in the present study is the effects of repeated periods of food deprivation on physiological and visual responding. There is some evidence in the literature to suggest that repeated deprivation periods result in adaptive changes which make the organism more fit to undergo the condition on subsequent occasions. Rogers (personal communication) found that human Ss who served in two food deprivation experiments showed less extreme physiological changes in the second experiment. Also, four human Ss who underwent five successive two and a half day fasts separated by five to six week intervals showed higher blood sugar levels and better reaction times and pattern tracing performance during the fifth fast as compared to the first (Taylor, Brozek, Henschel, Mickelsen, and Keys, 1945). On the basis of this evidence, a second food deprivation period was included to assess adaptation effects to food deprivation as measured by both physiological and visual responses.

CHAPTER II

METHOD

Description of subjects

Ten male undergraduates ranging in age from 17 to 24 years served as Ss. They were selected from a group of applicants on the basis of a rigorous physical examination and a Snellen Chart test for visual acuity (20/20 corrected vision required). Compensation for their services during the 22 days of testing included meals, housing and 150.00 dollars, the latter being contingent on their satisfactory service for the entire testing period. Subjects were roomed in a house near the testing facilities and took their specially prepared meals at the University cafeteria. In order to prevent their breaking the feeding schedule, E attempted to keep Ss under constant surveillance during all hours of the day and night. Assignment to experimental (food deprived, Exp. group) and control (continuous feeding, Cont. group) conditions was accomplished on Day 1 by means of drawing numbered slips of paper from a container. One Exp. group S became seriously ill following the first deprivation period and had to be released from the study for hospitalization.

General procedure

The general conditions and procedures are described in this section while the various pieces of apparatus used and the specific procedures followed for each class of measures are given in following sections.

The course of events for experimental days proceeded as follows. Subjects were awakened at 7 a.m. after which urine samples were collected and body weights taken. They then went to the laboratory where blood samples were drawn and at 9 a.m., went to breakfast. On days scheduled for food deprivation, the experimental Ss remained in the laboratory during meal times. At 9:30 a.m., Ss returned to the laboratory and testing began on the tasks listed below, continuing until the 1 p.m. lunch period. Testing resumed at 1:30 p.m. and terminated at 6 p.m. for dinner. After dinner, Ss returned to their quarters and remained there until the following day.

The time of testing a particular S on each of the experimental tasks was held constant from day to day and equal numbers of experimental and control Ss were run simultaneously, where possible, or alternated in time where simultaneity was not possible. Thus, while the time between testing and last food intake varied between Ss, this time period was constant within Ss across the 22-day period and was, on the average, equal between groups.

The standard diet consisted of 3 meals a day administered at the times shown above and was designed to be of sufficient caloric value to maintain body weight. The feeding schedule for the Exp. group consisted of a five day stabilization period on the standard diet followed by 72 hours of complete food deprivation. This was followed by a six day recovery period on the standard diet, then a second 72 hour food deprivation period and finally, a second five day recovery period. The Cont. group received the standard diet throughout the 22 day course of the experiment. Both groups were allowed free water intake throughout. Table 1 shows the Exp. group feeding and deprivation schedule along with the testing schedule for both groups.

It should be mentioned that, while some of the measures in Table 1 were taken by Dr. T. A. Rogers as part of a separate study, they were made available to the author as additional dependent variable data. These measures were weight loss, chemical analysis of urine and blood and pulse

Table 1

Feeding Schedule for the Experimental Group and Testing Schedules

for both Experimental and Control Groups

Day	Feeding			Visual Measures		Physiological (Resting)		Hunger and Fatigue Scale		Blood Samples (8:00 a.m.)	Physiological (Activity)
	B	L	D[a]	AM	PM	AM	PM	AM	PM		
1	x	x	x[b]								
2	x	x	x								
3	x	x	x								
4	x	x	x	x	x	x	x	x	x	x	x
5	x	x	x	x	x	x	x	x	x		x
6	x			x	x	x	x	x	x	x	x
7				x	x	x	x	x	x	x	x
8				x	x	x	x	x	x	x	x
9		x	x	x	x	x	x	x	x	x	x
10	x	x	x	x	x	x	x	x	x		x
11	x	x	x	x	x	x	x	x	x	x	x
12	x	x	x								x
13	x	x	x								
14	x	x	x	x	x	x	x	x	x		x
15	x			x	x	x	x	x	x	x	x
16				x	x	x	x	x	x	x	x
17				x	x	x	x	x	x	x	x
18		x	x	x	x	x	x	x	x	x	x
19	x	x	x	x	x	x	x	x	x		x
20	x	x	x	x	x	x	x	x	x	x	x
21	x	x	x	x	x	x	x	x	x		x
22	x	x	x	x	x	x	x	x	x	x	x

[a]Breakfast (B), Lunch (L), Dinner (D)
[b]x = Administered

rate and blood pressure taken before, during, and after exercise. Table 1 lists the schedule of sessions during which these measures were taken, with the exception of urine collection. For the latter, each S collected his own urine during each 24 hour period and turned it in to the laboratory the following morning.

Visual threshold and brightness matching

Apparatus. Two pieces of apparatus were used in order to permit measures to be taken twice each day on each S. Preliminary tests showed no significant difference between results obtained from the two apparatus assemblies. Furthermore, each S was trained on one of the two apparatus and remained on that apparatus throughout the experiment.

Apparatus 1 consisted of two separate light sources, one to the right eye and one to the left eye. The components for the right eye light path consisted of a Kodak Carousel Projector Model 550, whose light source was a General Electric 500w, 115-120 V DFW projection bulb. Proceeding from this light source to the eye, the light pathway contained the following components. First, there were two condenser lenses separated by heat absorbing glass. Next, for variation of light luminance, a mechanism permitted neutral Wratten filter slides to be inserted into the pathway by means of remote electrical control. Eighty slides were contained in a circular slide holder which was mounted on top of the projector. With S operating the remote control, 80 discrete 0.02 log unit changes in luminance could be obtained, ranging from 0.00 to 1.60 log units. The light path then contained (a) a Kodak Projection Zoom lens; (b) milk white diffusing glass; (c) a box to hold additional neutral Wratten filters for large steps in luminance and also to hold the t-field pattern slide; (d) a fixation pattern slide; and finally (e) a stereoscope in which a prism of 5° refracting angle was mounted.

The left eye light pathway contained the same components as those listed above with the following exceptions. The 500w projection bulb, two condensing lenses and heat absorbing glass were present but not contained in a Kodak projector. Thus, the mechanism for introducing 0.02 log unit Wratten filters and the Zoom lens were not necessary and were omitted from the left eye pathway.

The neutral Wratten filters contained in the box in either pathway allowed E to control the luminance to either eye in relatively large, discrete steps. The pattern slides in either pathway defined the size and shape of the t- and match-field (m-field) patterns. The threshold t-field pattern and the isolated m-field patterns were circular holes, 2 mm. in diameter, punched in black cardboard which was then mounted between pieces of 2 in. x 2 in. slide cover glass. For the enhancement and inhibition patterns the t-field was surrounded by a circular annulus of light of which the luminance was either 0.10 log mL. less than the t-field luminance (enhancement) or 0.10 log mL. greater (inhibition). The enhancement slide was a circular hole, 5 mm. in diameter, punched in black cardboard to define the outer limits of the i-field. The surrounded t-field was obtained by removing a 2 mm. circle from a 0.10 Wratten filter and centering the circle inside the i-field. The inhibition pattern consisted of a 2 mm. circular patch of 0.10 Wratten filter centered in the 5 mm. circular hole. The components were then sealed between 2 in. x 2 in. pieces of slide cover glass.

The fixation pattern slide for each pathway was a 2 in. square of clear plastic with a 16 mm. hole drilled in its center. The slide was painted black except for the bottom half of the circle's edge and the bottom edge of the slide. A small red bulb located adjacent to the bottom edge projected light up through the slide and illuminated the unpainted lower half of the circle. Its luminance was controlled by a potentiometer adjustable by S.

A baffle in the stereoscope between the two light pathways insured that the left eye saw only the left side light and the right eye saw only the right side light. The prisms mounted in the stereoscope made it possible for S to superimpose or to fuse the two fixation patterns during the brightness matching conditions. Thus, the binocular view, as seen by S with the fixation patterns fused, was that of a single, dimly lighted half circle, opening upward with the left eye and right eye patterns located adjacent to its left and right borders respectively (Fig. 1). When thresholds were taken, the left eye light and left fixation light were turned off.

With the eyes located 347 mm. from the patterns, the t- and m-fields of 2 mm. diameter subtended a visual angle of 20', the 5 mm. i-field subtended 49' and the 16 mm. fixation pattern subtended 78'. Vision was foveal, since, with Ss instructed to fixate the midpoint of the fixation pattern, the t- and m-field patterns fell within 60' of the fixation point (Polyak, 1941).

Apparatus 2 had as light sources two 200w, 120v Sylvania projection bulbs operated through an Ohmite potentiometer. Proceeding from the light sources, both pathways contained diffusing glass followed by fixed and moveable polaroids. All components beyond the polaroids were identical to those in Apparatus 1. The subject could manipulate the luminance in the right pathway continuously over a range of 0.70 log units by means of knob control which rotated the moveable polaroid.

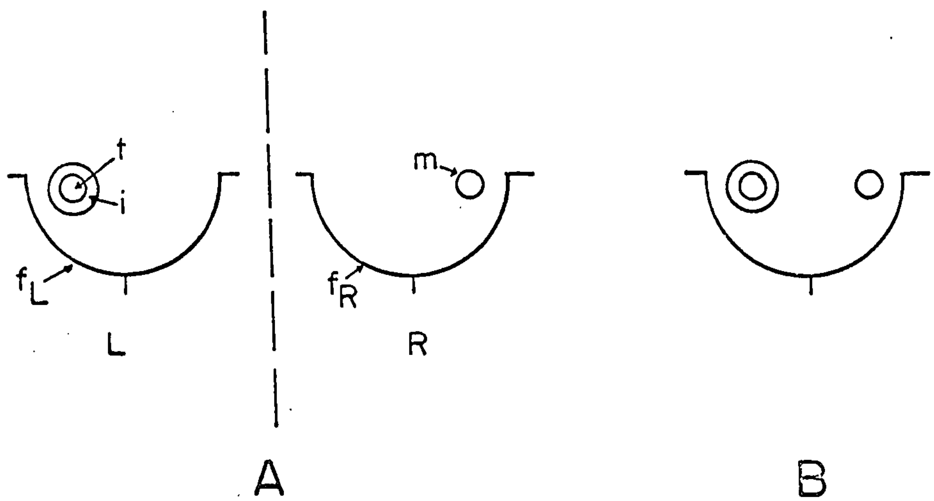

Fig. 1. (A) Test and inducing patterns to the left eye (L) only and match pattern to the right eye (R) only as seen monocularly. (B) The binocular view when fixation patterns f_L and f_R are fused.

Procedure. After a 15 minute period of dark adaptation, S was led into an air conditioned dark testing booth where he adjusted the height of the stool and chin rest, the latter being used to restrict head movements. With the luminance set below threshold, S began making threshold responses using the right eye by the method of adjustment (Guilford, 1954), i.e., he increased the luminance by either operating the electrical remote control button in the case of Apparatus 1, or by turning the polaroid control knob on Apparatus 2. When S first detected the light, he sounded a buzzer after which E recorded the response and reset the luminance to a value below threshold. Two practice trials were given followed by six text trials which were used as experimental data.

During a 30 second rest period, E turned on the left eye light source (t-field) and adjusted Wratten filters for the isolated match trials. S adjusted the intensity of the left fixation pattern, fused the two fixation patterns into the binocular view described above, and began increasing the luminance of the m-field until it appeared equal in brightness to the t-field. Using the adjustment procedure described above, two practice trials and six test trials were recorded. Continuing with this procedure and interspersed by 30 sec. rest periods, a like number of practice and test trials were conducted for the enhancement pattern and inhibition pattern. The time required to complete an experimental session, including dark adaptation time, was approximately 45 min. Threshold and matching sessions were conducted twice a day for each S (Table 1).

To control for practice effects, each S was given six training sessions during which he was instructed to establish a stable criterion for making threshold and brightness judgments and to strive for accuracy in his settings. Due to scheduling difficulties, Day 3 (pm) was the first experimental session in which all Ss were tested on every visual response measure.

Resting state physiological measures

Immediately after completing the visual session, S was taken to an adjoining experimental room where, after sitting quietly for 5 minutes, blood pressure (BP), oral temperature and pulse rate measures were taken.

The apparatus for systolic and diastolic BP was a sphygmomanometer (W. A. Baum Co., Inc.) consisting of an inflatable cuff, a mercury manometer, an inflating bulb with a controllable exhaust, and a stethoscope. Standard procedure as set forth by the American Heart Association was used. Three measures were recorded in each session, with the mean of the two closest measures being used as the BP measure for the session.

Oral temperature was taken with a clinical thermometer (Ballo Thermometer Co., Leesburg, Fla.) during a 3 min. period. Pulse rate was measured over one minute periods by counting wrist pulse beats. The mean number of beats per min. from two separate one min. periods was recorded.

Hunger and fatigue scale

Following the physiological measures, Ss were asked to respond to two seven item scales. The hunger scale consisted of seven items expressing degrees of hunger ranging from "satiated, not hungry...." (scale value 1) to "hungriest I have been...." (scale value 7). The fatigue scale was similarly constructed but of items expressing seven degrees of fatigue. Ss were instructed to place a check mark beside the item which best described his condition at that time. The scales are shown in Appendix A.

Measures of visual acuity and performance on a motor skill were also taken during the course of the experiment. However, because apparatus failure at crucial times nullified the usefulness of these measures, they are not included in the present report.

CHAPTER III

RESULTS

The results are grouped into five separate sections on the basis of type of response variable. The data presented in the tables are group means calculated from the raw scores of each experimental session. On the other hand, the results graphed in Figs. 2 - 10 represent the following transformation of the raw data. For each *S*, the mean of all sessions up to Day 6 (am) was calculated and differences between this overall mean and each session value (either a mean or single score) were determined. This transformation equated the groups in the first pre-deprivation period [Day 3 (pm) to day 5 (pm)] and permitted the assessment of the mean amount of change which occurred throughout the course of the experiment.

The statistical analysis for each response measure consisted of a three way analysis of variance (group X feeding schedule X replication) with repeated measures on two variables (Winer, 1962, p. 319). Due to the small number of *S*s per group and the diurnal variation in responding, the data were grouped into the following six points: (a) Pre-deprivation period 1 [Days 3 (pm) through 6 (am)]; (b) Deprivation period 1 [Days 6 (pm) through 9 (am)]; (c) Post-deprivation period 1 [Days 9 (pm) through 11 (pm)]; (d) Pre-deprivation period 2 [Days 14 (am) through 15 (am)]; (e) Deprivation period 2 [Days 15 (pm) through 18 (am)]; and (f) Post-deprivation period 2 [Days 18 (pm) through 22 (pm)]. Due to the fact that the groups were equated during Pre-deprivation period 1 (Pre-dep 1) and were treated differently only during Deprivation period 1 (Dep 1) and Deprivation period 2 (Dep 2), it was unlikely that main effects would be significant. Thus, the test of differential responding of the groups was the group X feeding schedule and group X replication interactions.

Experiment I - Visual response

Group means of absolute threshold and brightness matching responses are presented in Table 2. In Fig. 2, the means of the transformed values, as described above, are graphed for the Exp. and Cont. groups. The graph of the absolute threshold change shows that thresholds decreased for both groups throughout Pre-dep 1 and Dep 1, but that with the resumption of feeding during Post deprivation period 1 (Post-dep 1), the Exp. group's threshold increased to the value near its initial level and remained relatively stable during the remainder of the experiment. The Cont. group, on the other hand, remained at a lower threshold level during Post-dep 1 and throughout the remainder of the experiment.

The results of the analysis of variance (Table 3) show no significant difference between Exp. and Cont. groups ($p = .06$, d.f. = 1,7) nor any simple effect due to replication. The significant effect of feeding schedule ($p < .01$, d.f. = 2,14) indicates that with groups and replication combined, a significant change in threshold occurred between the Pre-dep, the Dep, and the Post-dep periods. From an examination of Fig. 2, it appears that this effect is mainly attributable to the threshold decrease from Pre-dep 1 to Dep 1 which both groups displayed. The significant group X feeding schedule interaction indicates that the Exp. and Cont. groups responded differently across the feeding schedule with the major differences occurring during the Post-dep 1 period in which the Exp. group threshold increased (see Fig. 2). The group X replication interaction ($p < .01$, d.f. = 1,7) shows that the direction of threshold change from the first feeding cycle to the replication differed for Exp. and Cont. groups with the former showing an increase and the latter a decrease in threshold from the first feeding cycle to the replication (Fig. 2).

Table 2

Means of Experimental and Control Groups Across Days for Threshold and Three Brightness Matching Responses in Log Millilamberts

Day	Threshold		Isolated		Enhancement		Inhibition	
	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.
4am	3.30	3.13	.27	.28	.41	.40	1.00	1.06
4pm	3.27	2.88	.31	.31	.41	.35	1.12	1.03
5am	3.39	2.94	.27	.45	.40	.47	1.18	1.09
5pm	3.36	2.91	.34	.40	.40	.45	1.09	.77
6am	3.51	3.17	.37	.35	.49	.49	1.29	.96
6pm[a]	3.50	3.32	.34	.33	.47	.48	1.28	1.26
7am[a]	3.46	3.34	.23	.34	.40	.46	.95	1.15
7pm[a]	3.43	3.36	.32	.34	.38	.47	1.01	1.12
8am[a]	3.44	3.40	.28	.39	.54	.53	1.06	1.28
8pm[a]	3.64	3.46	.36	.42	.54	.50	1.08	1.33
9am[a]	3.58	3.58	.33	.35	.42	.39	1.14	1.38
9pm	3.60	3.38	.28	.39	.40	.46	1.03	1.15
10am	3.28	3.58	.26	.34	.36	.45	1.08	1.12
10pm	3.24	3.56	.26	.31	.40	.45	1.00	1.10
11am	3.24	3.59	.26	.32	.39	.45	.98	1.14
11pm	3.24	3.44	.27	.36	.44	.45	1.02	1.18

(Table continued on next page)

Day	Threshold		Isolated		Enhancement		Inhibition	
	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.
14am	3.17	3.44	.23	.27	.34	.52	1.06	1.09
14pm	3.26	3.48	.22	.22	.42	.33	1.05	1.02
15am	3.27	3.36	.20	.33	.32	.42	1.04	1.00
15pm[a]	3.22	3.45	.20	.32	.35	.42	1.00	1.07
16am[a]	3.37	3.45	.22	.24	.36	.38	1.02	.99
16pm[a]	3.28	3.33	.26	.24	.38	.30	1.00	.93
17am[a]	3.34	3.42	.21	.34	.34	.49	1.04	1.03
17pm[a]	3.36	3.42	.27	.30	.34	.36	1.04	1.12
18am[a]	3.42	3.43	.26	.37	.34	.41	1.02	1.07
18pm	3.34	3.36	.16	.28	.28	.38	1.01	.91
19am	3.24	3.40	.10	.19	.16	.30	.90	.80
19pm	3.33	3.49	.14	.30	.29	.37	.97	1.02
20am	3.36	3.40	.07	.25	.20	.30	1.00	1.03
20pm	3.21	3.42	.20	.22	.29	.30	1.00	1.08
21am	3.33	3.42	.16	.30	.23	.39	.98	1.12
21pm	3.30	3.44	.20	.31	.15	.34	1.01	1.02
22am	3.06	3.67	.20	.29	.26	.34	.80	1.16
22pm	3.43	3.61	.17	.28	.30	.44	1.05	1.15

Note.--All values are negative.

[a]Experimental group starved.

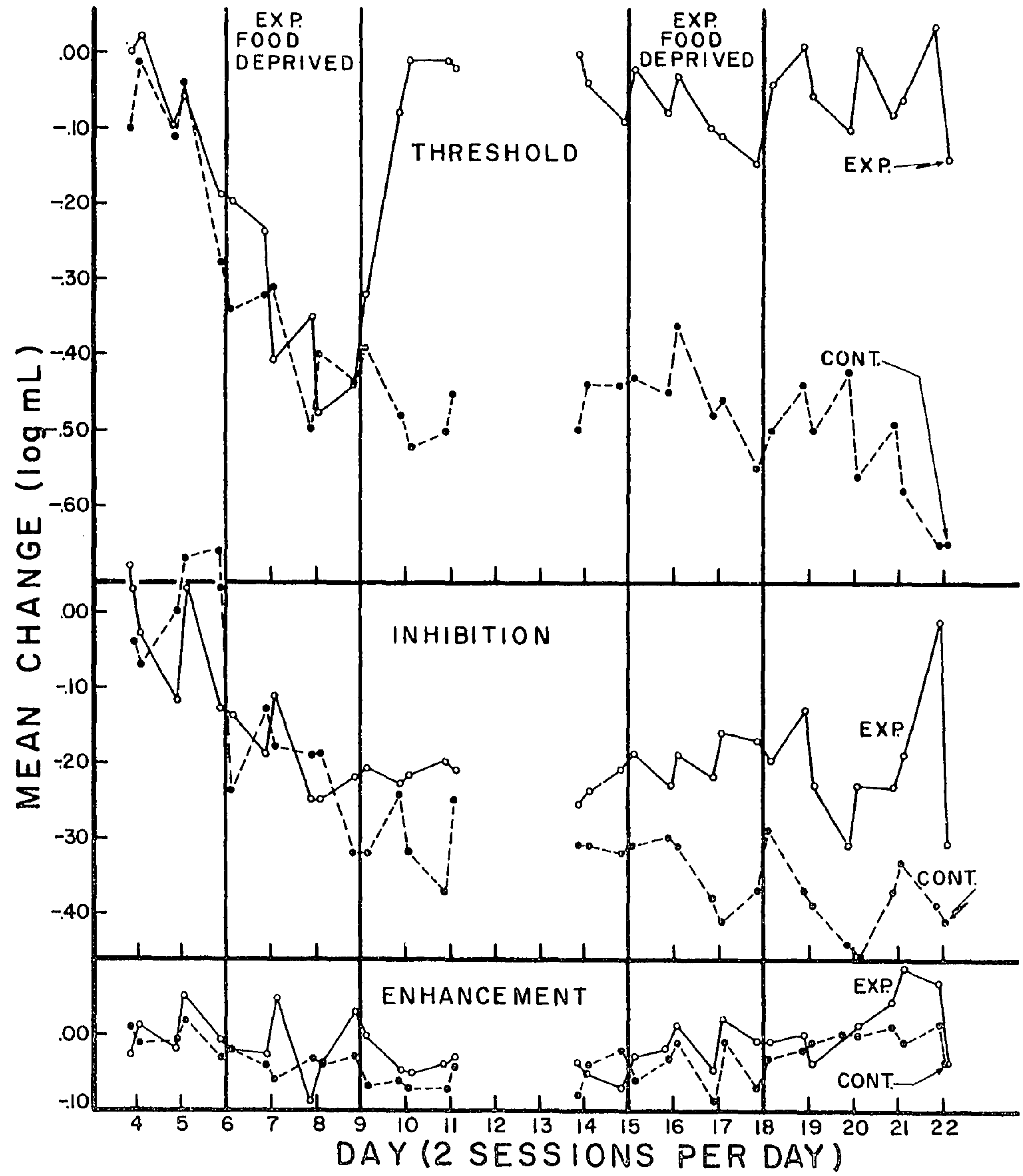

Fig. 2. Threshold and test-field brightness change as a function of feeding and deprivation schedule.

Table 3

Summary of Analysis of Variance of Change

in Threshold

Source	df	MS	F
Between	8		
Group (A)	1	1.02	5.30
Error (a)	7	.19	
Within	45		
Feeding Schedule (B)	2	.17	17.00**
A X B	2	.04	4.00*
Error (b)	14	.01	
Replication (C)	1	.02	1.00
A X C	1	.36	14.92**
Error (c)	7	.02	
B X C	2	.12	6.00*
A X B X C	2	.01	.74
Error (b X c)	14	.02	
Total	53		

*Significant at .05 level.

**Significant at .01 level.

The graph of the brightness contrast enhancement results (Fig. 2) shows the groups to be similar with little systematic change throughout the course of the experiment. The results of the analysis of variance (Table 4) show no significant group or group interaction effects. The graph of the inhibition results, on the other hand, shows that the curves separate during the Post-dep 1 period with the Exp. group responding at a higher level throughout the remainder of the experiment. The results of the analysis of variance (Table 5), however, show no significant group or group interaction effects to support the apparent group separation which occurred during the replication. A post analysis of the depression results, using the 23 means of each group as scores for the calculation of a t-test, showed that the group difference is significant at the .01 level. Thus, with a less conservative test, the inhibition results agree with the threshold results in showing a relative loss in sensitivity for the Exp. group when feeding is resumed in Post-dep 1.

Experiment II - Resting state physiological measures

Table 6 gives group means on the following measures taken after each visual session: oral temperature, pulse rate, systolic BP and diastolic BP. The mean amount of change for Exp. and Cont. groups is plotted in Fig. 3 and 4. The graph of temperature change (Fig. 3), despite large diurnal variation, appears to show systematic changes related to the feeding schedule. The Exp. group shows a temperature decrease in both Dep 1 and Dep 2 followed by temperature increases during the Post-dep periods. The Cont. group also shows lower mean temperatures during Dep 1 followed by an increase in Post-dep 1, but this pattern was not repeated in the replication data. The significant group X feeding schedule interaction ($p < .01$, d.f. = 2,14) supports these trends noted in Fig. 3 since

Table 4

Summary of Analysis of Variance of Change in Enhancement

Source	df	MS	F
Between	8		
Group (A)	1	.0044	2.32
Error (a)	7	.0019	
Within	45		
Feeding Schedule (B)	2	.0001	.06
A X B	2	.0013	.72
Error (b)	14	.0018	
Replication (C)	1	.0001	.06
A X C	1	.0001	.00
Error (c)	7	.0018	
B X C	2	.0093	4.89*
A X B X C	2	.0003	.16
Error (b X c)	14	.0019	
Total	53		

*Significant at .05 level.

Table 5

Summary of Analysis of Variance of Change in Inhibition

Source	df	MS	F
Between	8		
Group (A)	1	.0908	1.50
Error (a)	7	.0613	
Within	45		
Feeding Schedule (B)	2	.0947	11.55**
A X B	2	.0121	1.48
Error (b)	14	.0082	
Replication (C)	1	.2267	6.24*
A X C	1	.0423	1.16
Error (c)	7	.0363	
B X C	2	.0702	27.00**
A X B X C	2	.0006	.23
Error (b X c)	14	.0026	
Total	53		

*Significant at .05 level.

**Significant at .01 level.

Table 6

Means of Experimental and Control Groups Across Days for Oral Temperature (Degrees Fahrenheit), Pulse Rate (Beats/Minute), Systolic and Diastolic Blood Pressure (Millimeters of Mercury)

Day	Temperature		Pulse Rate		Systolic BP		Diastolic BP	
	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.
4am	98.1	98.9	69.5	71.0	93.5	98.6	56.2	60.8
4pm	98.2	98.9	75.8	71.5	101.8	103.8	56.8	61.6
5am	97.8	98.4	69.5	73.6	95.0	104.0	54.2	64.6
5pm	98.2	98.6	69.2	73.6	97.0	102.2	50.0	59.6
6am	97.9	98.1	69.0	72.6	98.5	100.4	50.8	57.4
6pm[a]	97.7	98.4	64.0	74.8	95.2	102.2	55.0	56.4
7am[a]	97.7	98.2	74.2	73.4	91.5	102.0	54.8	61.6
7pm[a]	97.7	98.3	70.8	73.8	92.0	101.2	55.0	59.6
8am[a]	97.5	98.0	67.5	72.0	93.0	97.8	56.5	60.4
8pm[a]	97.4	98.4	72.0	75.2	91.8	106.4	57.0	61.0
9am[a]	97.6	98.2	70.0	69.4	91.0	99.4	58.2	59.0
9pm	98.2	98.4	78.2	73.0	93.5	102.2	48.0	59.6
10am	97.8	98.4	69.8	73.8	90.0	102.4	48.0	60.0
10pm	98.3	98.6	70.8	75.0	94.0	104.2	43.8	61.8
11am	98.0	98.4	66.8	75.0	88.0	99.6	45.2	59.4
11pm	98.3	98.4	69.2	75.8	95.5	103.8	42.0	59.0

(Table continued on next page)

Day	Temperature		Pulse Rate		Systolic BP		Diastolic BP	
	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.
14am	97.8	98.3	68.5	72.4	87.0	102.8	44.0	57.8
14pm	98.0	98.6	71.8	74.2	90.0	100.0	41.5	58.6
15am	97.9	98.2	70.2	73.0	91.2	101.0	48.2	62.0
15pm[a]	98.3	98.6	68.0	75.4	87.0	102.0	49.5	58.8
16am[a]	97.4	98.1	68.2	72.8	86.0	101.4	54.5	61.2
16pm[a]	97.7	98.4	66.8	75.0	83.5	98.6	52.8	59.2
17am[a]	97.7	98.2	73.2	77.0	85.2	99.8	53.5	58.8
17pm[a]	97.8	98.5	71.5	79.0	88.8	100.4	56.2	60.4
18am[a]	97.4	98.4	68.2	77.6	85.2	103.8	58.2	61.2
18pm	98.0	98.6	82.2	78.8	87.8	105.6	43.5	59.2
19am	97.7	98.3	67.5	73.0	84.0	102.0	52.0	63.4
19pm	98.0	98.4	65.5	78.6	88.5	99.4	48.0	60.6
20am	97.6	97.8	64.2	75.6	87.5	99.2	46.8	60.4
20pm	98.0	98.2	66.8	76.2	90.5	103.4	49.0	60.0
21am	97.7	98.1	68.0	74.6	87.8	102.2	47.8	64.8
21pm	97.8	98.1	63.8	74.2	89.5	107.0	41.5	60.4
22am	97.9	98.2	66.0	74.0	88.5	101.2	44.8	63.0
22pm	98.0	98.5	69.2	82.2	90.2	107.4	47.8	61.0

[a]Experimental group starved.

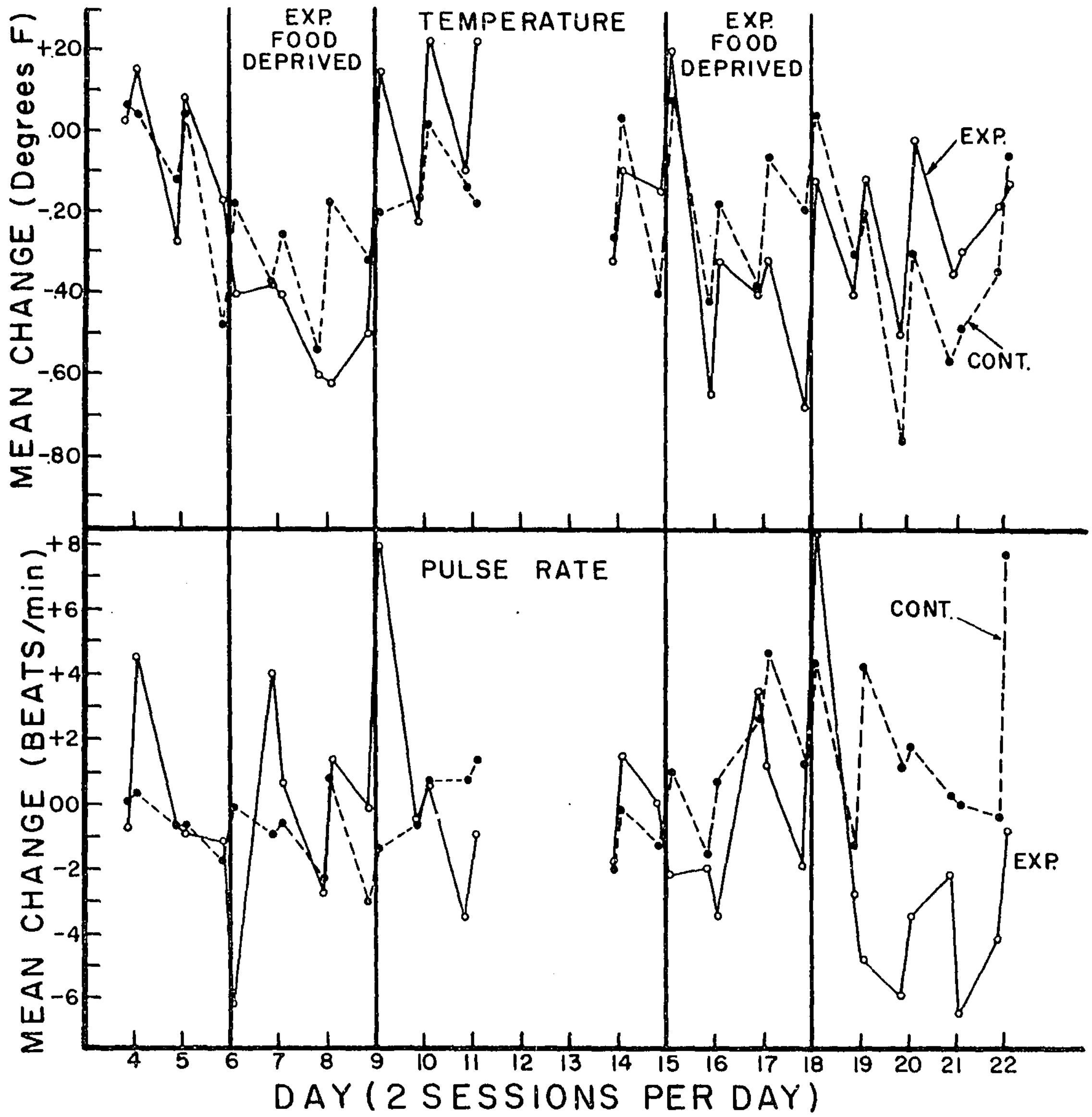

Fig. 3. Temperature and pulse rate change as a function of feeding and deprivation schedule.

the significant F ratio implies that with the original and replication combined, the groups responded differently across the feeding schedule (Table 7). The main source of difference seems to be due to the differential responding of the Cont. group from the original to the replication.

The graph of the pulse rate change (Fig. 3) shows no systematic change for either group across the feeding schedule. This is supported by the finding of no significant main or interaction effects in the analysis of variance (Table 8).

The systolic BP curves (Fig. 4) show an indication of a progressive decrease across the complete study for the Exp. group as compared to the Cont. group. In addition, there is an indication of a slight decrease in systolic BP during Dep 1 and Dep 2 for the Exp. group. The significant group effect ($p < .05$, d.f. = 2,14) and the group X replication effect ($p < .01$, d.f. = 1,7) support the evident separation of the groups over time (see Table 9).

The graph of the diastolic BP data (Fig. 4) shows sharp increases for the Exp. group in both Dep 1 and Dep 2 while the Cont. group remains at a relatively stable level throughout the course of the experiment. The significant group X feeding schedule interaction ($p < .01$, d.f. = 2,14) is evidence of the differential effects of the feeding schedule on the Exp. and Cont. groups (Table 10).

Group differences during Dep 1 and Dep 2 also appear in the pulse pressure data (Fig. 4) with the Exp. group showing a marked decrease in pulse pressure with food deprivation, followed by recovery to initial levels with the resumption of feeding in Post-dep 1 and Post-dep 2. The group X feeding schedule interaction ($p < .01$, d.f. = 2,14) supports the interpretation (Table 11).

Table 7

Summary of Analysis of Variance of Change in Temperature

Source	df	MS	F
Between	8		
Group (A)	1	.0031	.03
Error (a)	7	.1032	
Within	45		
Feeding Schedule (B)	2	.2223	14.16 **
A X B	2	.1221	7.78 **
Error (b)	14	.0157	
Replication (C)	1	.0696	4.17
A X C	1	.0009	.05
Error (c)	7	.0167	
B X C	2	.1471	17.10 **
A X B X C	2	.0053	.62
Error (b X c)	14	.0086	
Total	53		

**Significant at .01 level.

Table 8

Summary of Analysis of Variance of Change

in Pulse Rate

Source	df	MS	F
Between	8		
Group (A)	1	4.39	.16
Error (a)	7	27.53	
Within	45		
Feeding Schedule (B)	2	3.84	.73
A X B	2	7.48	1.43
Error (b)	14	5.24	
Replication (C)	1	8.52	.45
A X C	1	42.19	2.24
Error (c)	7	18.79	
B X C	2	2.67	.32
A X B X C	2	17.21	2.05
Error (b X c)	14	8.37	
Total	53		

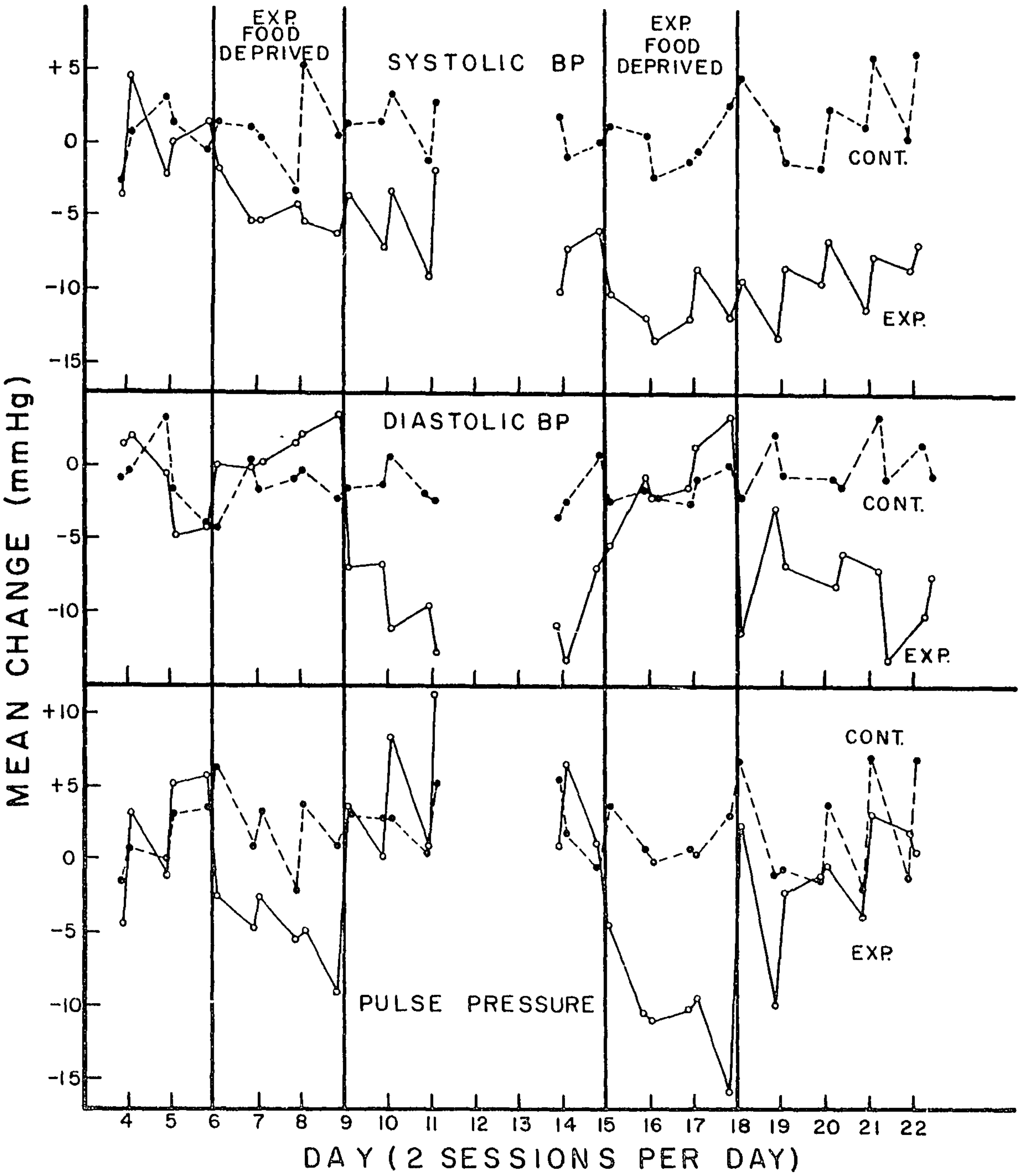

Fig. 4. Systolic BP, diastolic BP and pulse pressure change as a function of feeding and deprivation schedule.

Table 9

Summary of Analysis of Variance of Change

in Systolic Blood Pressure

Source	df	MS	F
Between	8		
Group (A)	1	670.20	12.09*
Error (a)	7	55.45	
Within	45		
Feeding Schedule (B)	2	13.58	1.86
A X B	2	30.29	4.14*
Error (b)	14	7.32	
Replication (C)	1	104.56	11.56*
A X C	1	133.84	14.80**
Error (c)	7	9.05	
B X C	2	3.84	.97
A X B X C	2	2.50	.64
Error (b X c)	14	3.93	
Total	53		

*Significant at .05 level.

**Significant at .01 level.

Table 10

Summary of Analysis of Variance of Change

in Diastolic Blood Pressure

Source	df	MS	F
Between	8		
Group (A)	1	261.79	4.31
Error (a)	7	60.68	
Within	45		
Feeding Schedule (B)	2	17.75	2.98
A X B	2	23.85	7.39**
Error (b)	14	59.11	
Replication (C)	1	7.80	.38
A X C	1	6.60	.56
Error (c)	7	9.78	
B X C	2	17.44	4.61*
A X B X C	2	59.21	3.27
Error (b X c)	14	42.02	
Total	53	12.85	

*Significant at .05 level.

**Significant at .01 level.

Table 11

Summary of Analysis of Variance of Change

in Pulse Pressure

Source	df	MS	F
Between	8		
Group (A)	1	103.78	.72
Error (a)	7	144.04	
Within	45		
Feeding Schedule (B)	2	23.90	8.14**
A X B	2	99.06	11.76**
Error (b)	14	143.18	
Replication (C)	1	12.17	4.81
A X C	1	41.09	2.09
Error (c)	7	17.85	
B X C	2	8.55	2.88
A X B X C	2	42.13	.46
Error (b X c)	14	6.70	
Total	53	14.60	

**Significant at .01 level.

With the exception of pulse rate, the resting state physiological measures show a direct relationship to hours of deprivation, i.e., oral temperature, systolic BP and pulse pressure decrease while diastolic BP increases with hours of deprivation. Diastolic BP and pulse pressure results are clearly interpretable in terms of the feeding schedule. Interpretation of oral temperature and systolic BP results, however, is not so clear cut. In the case of the former, the Cont. group also showed a temperature decrease in Dep 1 followed by an increase in Post-dep 1 suggesting that some variable other than food deprivation was affecting temperature.

With systolic BP, the failure of the Exp. group to show recovery to predeprivation levels following Dep 1 and Dep 2 suggests that either the diet or the time period between Dep 1 and Dep 2 was not sufficient to allow complete recovery. More important, however, is the fact that despite systematic changes in resting state physiological measures with food deprivation, none of the changes seem to be directly related to the visual response changes.

Experiment III - Activity state physiological measures

Whereas the physiological measures in Exp. II were taken during periods of rest immediately following the visual sessions, the measures in this section were taken before and after a five min. period of strenuous exercise. Group means for systolic BP, diastolic BP and heart rate are given in Tables 12, 13, and 14. The mean group changes are graphed in Fig. 5, 6, and 7. Inspection of the systolic BP curves (Fig. 5) under conditions of pre-exercise, post-exercise and recovery suggests a cumulative effect on the Exp. group from the original feeding schedule to the replication. This is shown by both the decreasing trend of the Exp.

Table 12

Mean Systolic Blood Pressure (Millimeters of Mercury)

for Experimental and Control Groups as a function of Feeding

and Deprivation Schedule Before, After and Following Recovery from Exercise

Systolic BP

Day	Pre-exercise		Post-exercise		Recovery	
	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.
4	114.5	121.8	167.5	170.8	118.5	124.4
5	116.0	118.4	167.0	180.4	126.5	129.6
6[a]	106.5	120.8	168.0	170.0	125.5	128.2
7[a]	109.0	116.8	165.0	166.4	122.5	131.4
8[a]	111.5	122.0	158.0	173.6	117.2	137.4
9am[a]	103.0	118.4	158.0	172.8	114.5	128.2
9pm	114.0		168.5		130.5	
10	104.0	115.4	170.0	175.6	115.5	133.2
11	104.5	113.2	173.0	172.4	121.2	128.2
12	111.0	117.6	166.8	168.6	118.5	122.6

(Table continued on next page)

Systolic BP

Day	Pre-exercise Exp.	Pre-exercise Cont.	Post-exercise Exp.	Post-exercise Cont.	Recovery Exp.	Recovery Cont.
14	102.0	123.2	160.5	174.8	105.2	129.8
15[a]	103.8	116.0	156.5	163.8	112.0	132.0
16[a]	99.0	120.4	143.5	173.2	103.8	126.6
17[a]	98.0	113.6	149.8	172.4	105.8	131.8
18am[a]	93.8	127.4	149.5	166.2	113.0	120.8
18pm	100.5		157.2		114.0	
19am	99.5	110.2	155.5	156.2	106.0	134.4
19pm		122.0		169.0		129.6
20	101.8	111.5	165.5	162.8	110.2	128.0
21	98.8	118.4	161.5	165.4	110.0	125.4
22	96.0	116.8	158.2	163.8	116.0	117.4

[a]Experimental group starved.

Table 13

Mean Diastolic Blood Pressure (Millimeters of Mercury)

for Experimental and Control Groups as a function of Feeding

and Deprivation Schedule Before, After and Following Recovery from Exercise

Diastolic BP

Day	Pre-exercise		Post-exercise		Recovery	
	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.
4	61.5	76.2	37.8	71.8	68.5	78.8
5	65.5	73.6	30.5	23.2	64.5	70.0
6[a]	61.0	63.6	33.5	41.2	75.2	66.6
7[a]	63.5	73.2	31.5	37.2	63.0	54.8
8[a]	60.5	62.4	38.5	21.4	62.5	64.0
9am[a]	70.0	71.6	47.0	23.8	68.0	69.2
9pm	51.5		31.0		54.8	
10	49.5	69.2	13.0	25.6	60.0	69.6
11	53.5	66.0	14.0	22.4	62.5	67.0
12	51.0	61.6	11.8	20.8	61.0	58.8

(Table continued on next page)

Day	Pre-exercise Exp.	Pre-exercise Cont.	Post-exercise Exp.	Post-exercise Cont.	Recovery Exp.	Recovery Cont.
14	48.0	64.4	8.0	14.4	54.5	58.8
15[a]	59.0	62.0	20.0	27.6	55.0	57.2
16[a]	59.0	56.0	28.5	9.6	57.5	64.0
17[a]	65.5	71.6	30.3	17.6	58.0	66.2
18am[a]	61.0	66.8	23.8	16.0	57.8	66.0
18pm	47.0		7.5		47.5	
19am	49.2	63.0	26.5	14.0	56.5	72.4
19pm		56.6		6.4		64.8
20	51.0	67.6	13.8	17.6	58.0	68.0
21	54.0	63.2	8.3	17.6	55.5	52.8
22	54.5	65.0	15.5	19.2	54.5	72.4

[a]Experimental group starved.

Table 14

Mean Pulse Rate (Beats/Minute)

for Experimental and Control Groups as a Function of Feeding

and Deprivation Schedule Before, After and Following Recovery from Exercise

	Pulse Rate					
Day	Pre-exercise		Post-exercise		Recovery	
	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.
4	88.5	91.4	135.0	140.0	102.8	105.6
5	84.8	88.4	142.0	134.8	96.5	95.8
6[a]	83.2	85.8	141.2	132.8	93.8	99.2
7[a]	84.4	87.0	150.5	132.4	101.8	98.8
8[a]	82.8	86.8	144.5	134.2	99.2	102.2
9am[a]	81.2		150.0		98.0	
9pm	81.0	85.6	153.2	129.8	104.0	96.2
10	82.5	90.6	145.2	133.2	93.5	105.0
11	80.8	87.6	146.0	133.2	92.0	101.6
12	74.5	85.0	134.0	134.4	89.5	100.8

(Table continued on next page)

Day	Pre-exercise Exp.	Pre-exercise Cont.	Post-exercise Exp.	Post-exercise Cont.	Recovery Exp.	Recovery Cont.
14	77.0	87.2	134.8	133.2	89.5	99.0
15[a]	87.0	88.4	134.8	135.0	91.2	102.6
16[a]	78.2	89.2	141.2	139.0	93.0	101.6
17[a]	78.0	87.0	147.0	139.6	97.8	101.6
18am[a]	76.2	88.2	153.2	139.8	98.0	103.6
18pm	90.0		154.5		102.0	
19am	76.8	93.4	140.2	135.0	84.5	96.8
19pm		93.6		138.8		101.4
20	76.5	87.4	135.0	135.8	86.5	101.4
21	70.5	86.6	136.5	136.8	83.8	99.6
22	75.8	86.4	138.5	139.6	90.5	100.8

[a]Experimental group starved.

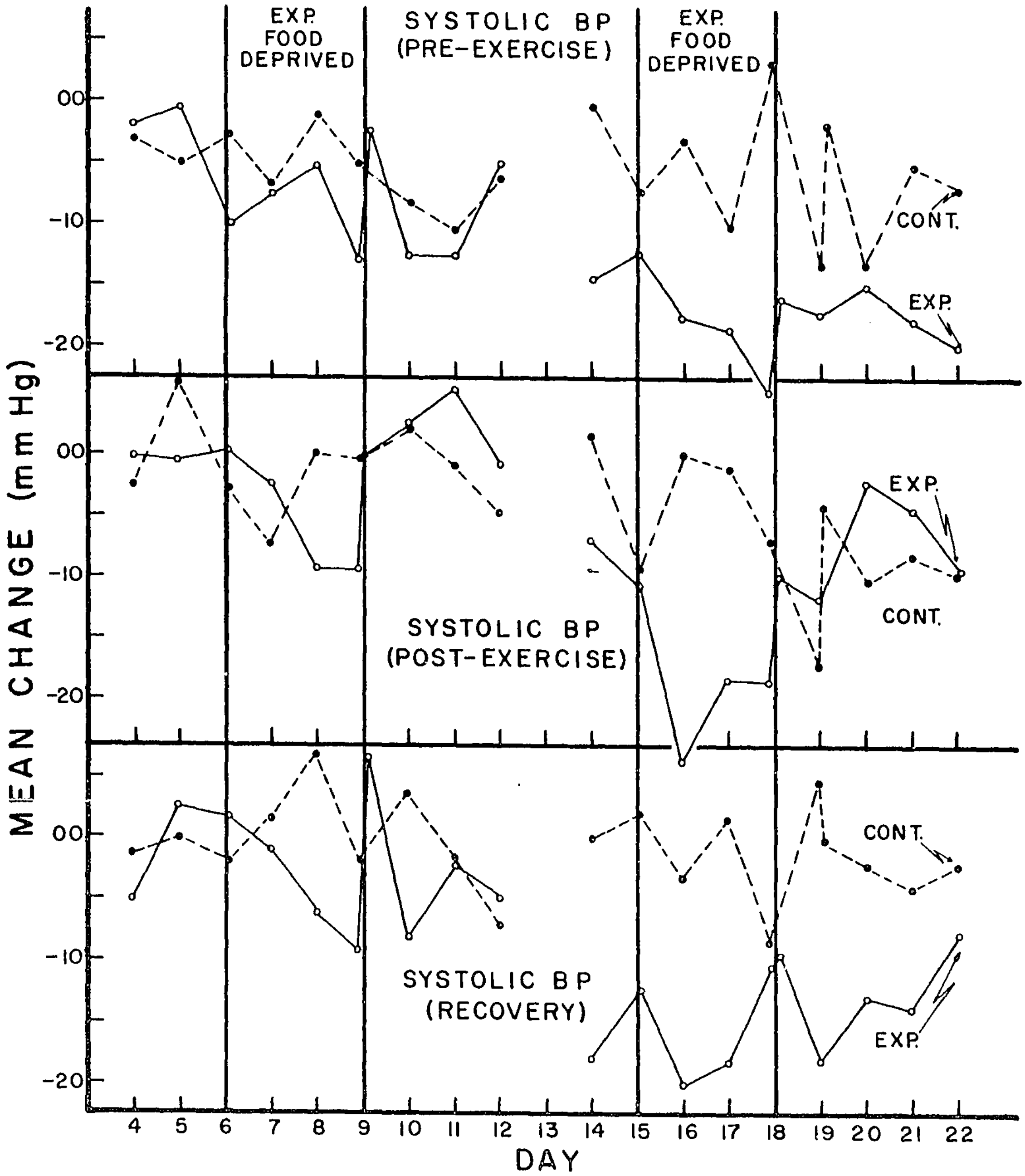

Fig. 5. Systolic BP change as a function of feeding and deprivation schedule.

group and the increased separation of Exp. and Cont. group curves during the replication. The group X replication interaction, which tests this trend, is significant for the pre-exercise (Table 15) and recovery periods (Table 17) but not for the post-exercise period (Table 16). The Exp. group curves also suggest effects due to feeding schedule since the point of greatest change is reached during the deprivation period in all cases. However, none of the group X feeding schedule interactions were significant.

The diastolic BP graphs (Fig. 6) also show a progressive decrease from the original feeding schedule to the replication with the main effects of replication being significant for pre-exercise, post-exercise and recovery (Tables 18, 19, and 20). However, the non-significant group X replication effect suggests that the rate of decrease for the two groups is the same. In addition, the increase in the diastolic BP which the Exp. group displays during Dep 1 and Dep 2 (Fig. 6) is significant for the pre-exercise and post-exercise conditions but not for the recovery condition (see the group X feeding schedule interactions, Tables 18, 19, and 20).

The graph of pulse rate change (Fig. 7) shows that while the Cont. group remains relatively stable for pre-exercise, post-exercise and recovery, the Exp. group displays progressively lower pulse rates across days with increases occurring during Dep 1 and Dep 2 for post-exercise and recovery conditions. However, as was the case with the resting state pulse rate means shown in Fig. 3 (Exp. II), none of the main or interaction effects during pre-exercise, which is essentially a resting state, is significant (Tables 21, 22, and 23). On the other hand, the significant group X replication and group X feeding schedule interactions for

Table 15

Summary of Analysis of Variance

of Change in Pre-Exercise Systolic Blood Pressure

Source	df	MS	F
Between	8		
Group (A)	1	483.50	5.78*
Error (a)	7	83.66	
Within	45		
Feeding Schedule (B)	2	68.10	5.61*
A X B	2	205.23	2.21
Error (b)	14	80.80	
Replication (C)	1	36.57	42.89**
A X C	1	469.53	18.31**
Error (c)	7	200.47	
B X C	2	10.95	.14
A X B X C	2	11.44	.25
Error (b X c)	14	20.95	
Total	53	83.51	

*Significant at .05 level.

**Significant at .01 level.

Table 16

Summary of Analysis of Variance

of Change in Post-Exercise Systolic Blood Pressure

Source	*df*	*MS*	*F*
Between	8		
Group (A)	1	181.55	.27
Error (a)	7	670.38	
Within	45		
Feeding Schedule (B)	2	93.40	1.19
A X B	2	211.40	2.69
Error (b)	14	78.44	
Replication (C)	1	822.83	11.23*
A X C	1	120.88	1.65
Error (c)	7	73.29	
B X C	2	35.16	.65
A X B X C	2	36.26	.67
Error (b X c)	14	54.39	
Total	53		

*Significant at .05 level.

Table 17

Summary of Analysis of Variance

of Change in Recovery State Systolic Blood Pressure

Source	df	MS	F
Between	8		
Group (A)	1	1050.20	3.94
Error (a)	7	266.40	
Within	45		
Feeding Schedule (B)	2	75.76	.92
A X B	2	101.10	1.23
Error (b)	14	82.40	
Replication (C)	1	783.00	14.58**
A X C	1	570.10	10.62*
Error (c)	7	53.70	
B X C	2	48.40	.89
A X B X C	2	17.60	.32
Error (b X c)	14	54.40	
Total	53		

*Significant at .05 level.

**Significant at .01 level.

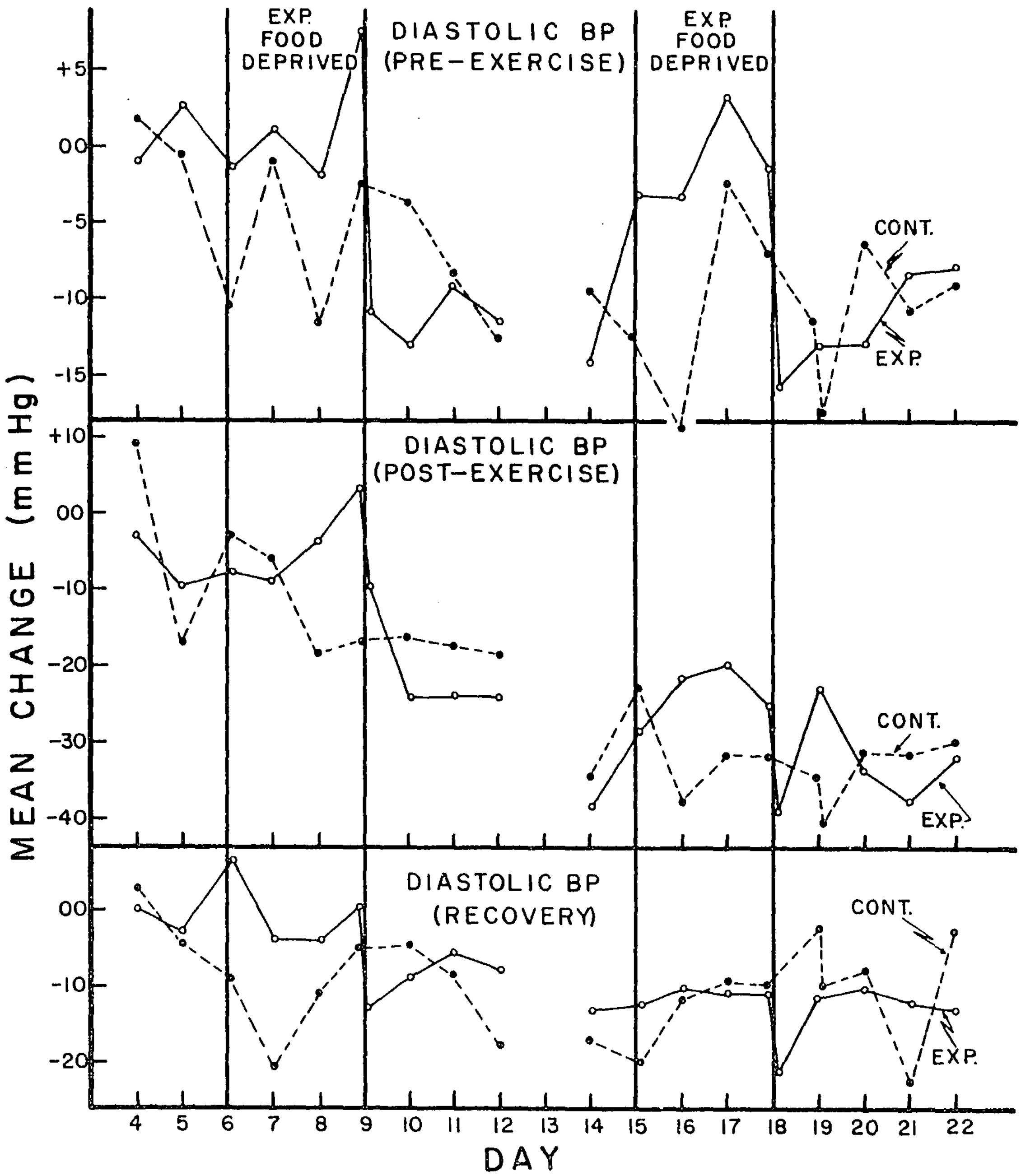

Fig. 6. Diastolic BP change as a function of feeding and deprivation schedule.

Table 18

Summary of Analysis of Variance

of Change in Pre-Exercise Diastolic Blood Pressure

Source	df	MS	F
Between	8		
Group (A)	1	97.38	1.84
Error (a)	7	52.88	
Within	45		
Feeding Schedule (B)	2	208.07	14.32**
A X B	2	99.86	6.87**
Error (b)	14	14.53	
Replication (C)	1	305.35	11.53*
A X C	1	4.42	.17
Error (c)	7	26.48	
B X C	2	57.45	2.07
A X B X C	2	3.47	.12
Error (b X c)	14	27.76	
Total	53		

*Significant at .05 level.

**Significant at .01 level.

Table 19

Summary of Analysis of Variance

of Change in Post-Exercise Diastolic Blood Pressure

Source	df	MS	F
Between	8		
Group (A)	1	9.1	.01
Error (a)	7	1683.8	
Within	45		
Feeding Schedule (B)	2	707.5	5.74*
A X B	2	720.6	5.85*
Error (b)	14	123.2	
Replication (C)	1	2969.2	14.01**
A X C	1	3.0	.01
Error (c)	7	212.0	
B X C	2	646.7	3.69
A X B X C	2	40.5	.23
Error (b X c)	14	175.4	
Total	53		

*Significant at .05 level.

**Significant at .01 level.

Table 20

Summary of Analysis of Variance

of Change in Recovery Diastolic Blood Pressure

Source	df	MS	F
Between	8		
Group (A)	1	90.33	.54
Error (a)	7	166.39	
Within	45		
Feeding Schedule (B)	2	29.37	.58
A X B	2	45.31	.90
Error (b)	14	50.34	
Replication (C)	1	527.35	6.68*
A X C	1	88.65	1.12
Error (c)	7	78.92	
B X C	2	288.87	6.81**
A X B X C	2	26.30	.62
Error (b X c)	14	42.44	
Total	53		

*Significant at .05 level.

**Significant at .01 level.

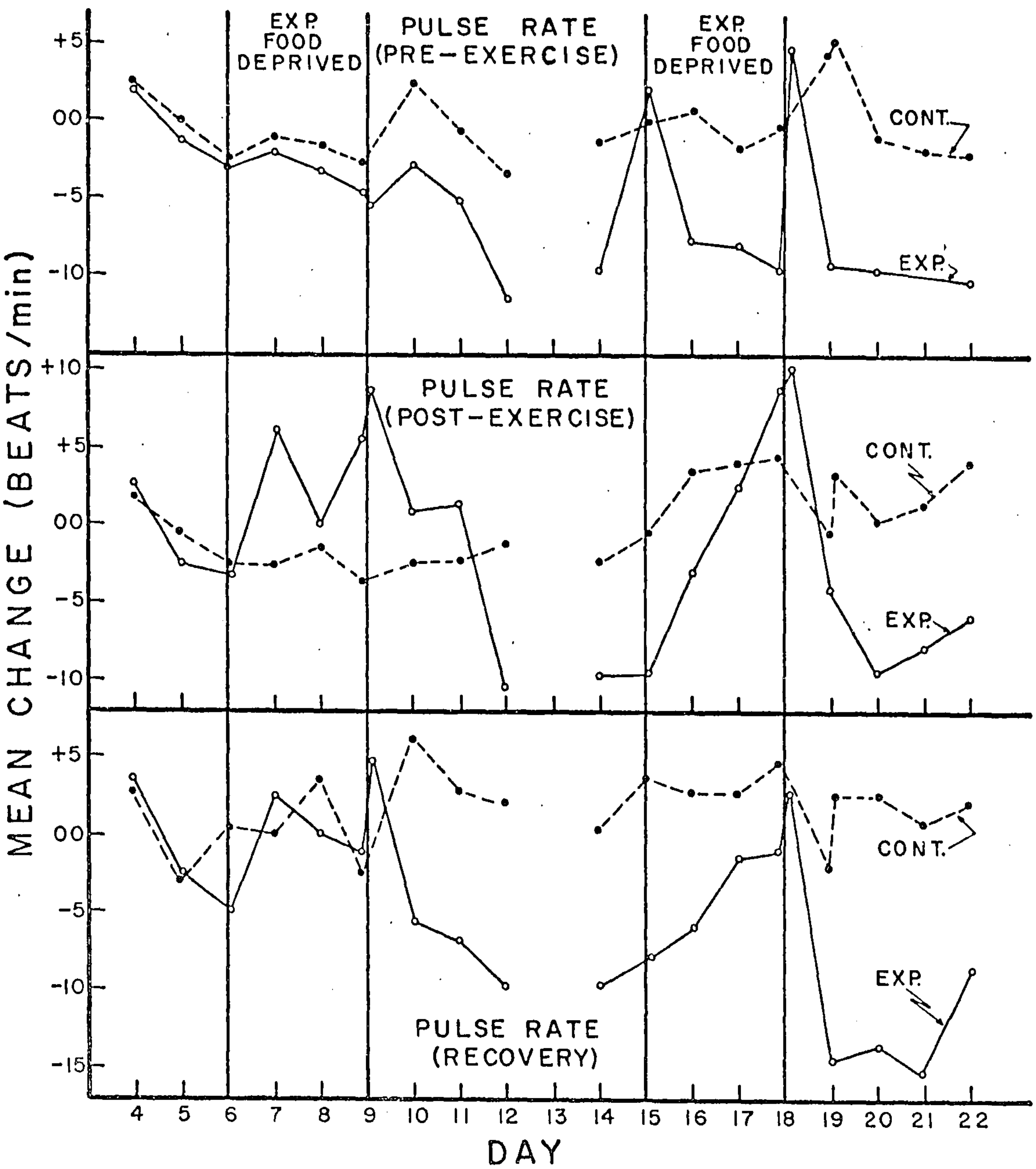

Fig. 7. Pulse rate change as a function of feeding and deprivation schedule.

Table 21

Summary of Analysis of Variance of Change

in Pre-Exercise Pulse Rate

Source	df	MS	F
Between	8		
Group (A)	1	278.97	2.42
Error (a)	7	115.04	
Within	45		
Feeding Schedule (B)	2	20.32	1.48
A X B	2	35.14	2.56
Error (b)	14	13.72	
Replication (C)	1	12.57	.24
A X C	1	59.48	1.14
Error (c)	7	52.23	
B X C	2	4.37	.30
A X B X C	2	3.61	.25
Error (b X c)	14	14.38	
Total	53		

Table 22

Summary of Analysis of Variance of Change

in Post-Exercise Pulse Rate

Source	df	MS	F
Between	8		
Group (A)	1	7.39	.04
Error (a)	7	177.30	
Within	45		
Feeding Schedule (B)	2	111.72	10.26**
A X B	2	53.82	4.94
Error (b)	14	10.89	
Replication (C)	1	.01	.00
A X C	1	229.40	6.14*
Error (c)	7	37.40	
B X C	2	55.73	4.01*
A X B X C	2	.19	.01
Error (b X c)	14	13.90	
Total	53		

*Significant at .05 level.

**Significant at .01 level.

Table 23

Summary of Analysis of Variance of Change

in Recovery State Pulse Rate

Source	df	MS	F
Between	8		
Group (A)	1	527.68	2.15
Error (b)	7	245.41	
Within	45		
Feeding Schedule (B)	2	28.90	.68
A X B	2	45.94	1.08
Error (b)	14	42.38	
Replication (C)	1	51.90	2.11
A X C	1	132.94	5.40
Error (c)	7	24.57	
B X C	2	18.57	2.58
A X B X C	2	12.38	1.72
Error (b X c)	14	7.20	
Total	53		

post-exercise (Table 22) suggest that the Exp. group's increase in pulse rate with deprivation and decrease from original to replication are significant effects immediately following exercise even though no significant changes occur during the pre-exercise resting condition. Although the Exp. group's recovery curves show trends similar to the post-exercise curves, only the group X replication interaction approaches significance ($p < .06$, d.f. = 1,7).

In summary, the above physiological measures show significant effects due to both feeding schedule and replication. None of these changes, however, appear to follow the trends found in the visual data.

Experiment IV - Weight loss, blood and urine analysis

Group means for weight, serum glucose and sodium level, and urine sodium and potassium excretion, are given in Tables 24 and 25. The mean change values across days are graphed in Fig. 8 and 9. The graph of weight change for the Exp. group (Fig. 8) shows progressive decreases in Dep 1 and Dep 2 followed by increases in Post-dep 1 and Post-dep 2 to levels somewhat below the respective Pre-dep levels. Thus the Exp. group failed to show complete weight recovery during the recovery periods. For the Cont. group, the continuous weight loss across days shows that the diet was not sufficient to maintain the initial body weight of the Cont. group. The significant group X feeding schedule interaction (Table 26) indicates differential trends for the two groups across feeding schedule, while the lack of a significant group X replication interaction shows that the downward trend from the original to replication is similar for both groups.

The graph of the serum glucose mean changes (Fig. 8) shows decreases in Dep 1 and Dep 2 for the Exp. group followed by increases in the Post-

Table 24

Mean Weight Loss (Kilograms),

Serum Glucose (Milliequivalents/100 Milliliters),

and Serum Sodium (Milligrams/100 Milliliters) as a Function

of Feeding and Deprivation Schedule for Experimental and Control

	Body Weight Loss		Serum Glucose		Serum Sodium	
Day	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.
4	- .02	≠ .02	97.5	95.4	140.2	139.7
5	- .24	- .17				
6	≠ .04	- .19	90.8	93.9	141.1	139.8
7[a]	- .98	- .30	84.2	93.0	138.8	141.2
8[a]	-1.94	- .36	71.2	90.5	139.4	141.4
9[a]	-2.87	- .37	61.0	93.6	140.0	143.2
10	-2.37	- .47				
11	-1.62	- .53	87.6	104.4	143.0	142.1
12	-1.10	- .57				
13	-1.24	- .76				
14	-1.44	- .62				
15	-1.23	- .67	90.6	93.9	139.2	143.2
16[a]	-2.37	- .77	77.5	90.7	136.8	140.0
17[a]	-3.36	- .88	66.5	92.9	137.7	142.9
18[a]	-4.23	- .94	68.4	90.0	136.5	141.8
19	-3.62	-1.03				
20	-2.67	-1.01	86.8	87.3	139.3	140.7
21	-2.29	-1.11				
22	-2.34	-1.12	89.1	92.7	143.4	143.4

[a]Experimental group starved.

Table 25

Mean Urine Sodium (Milliequivalents/Day)

and Potassium (Milliequivalents/Day) Excretion as a Function

of Feeding and Deprivation Schedule for Experimental and Control Groups

Day	Urine Sodium Exp.	Urine Sodium Cont.	Urine Potassium Exp.	Urine Potassium Cont.
4	219	188	75	69
5	200	181	60	55
6	111	175	58	61
7[a]	59	189	36	60
8[a]	42	184	41	58
9[a]	27	184	37	64
10	80	177	49	53
11	190	167	59	60
12	241	186	49	59
13	219	187	46	55
14	180	197	60	55
15	133	166	71	56
16[a]	51	189	44	65
17[a]	40	171	42	66
18[a]	20	183	33	67
19	63	177	48	61
20	168	168	57	56
21	180	163	43	54
22	201	172	56	61

[a]Experimental group starved.

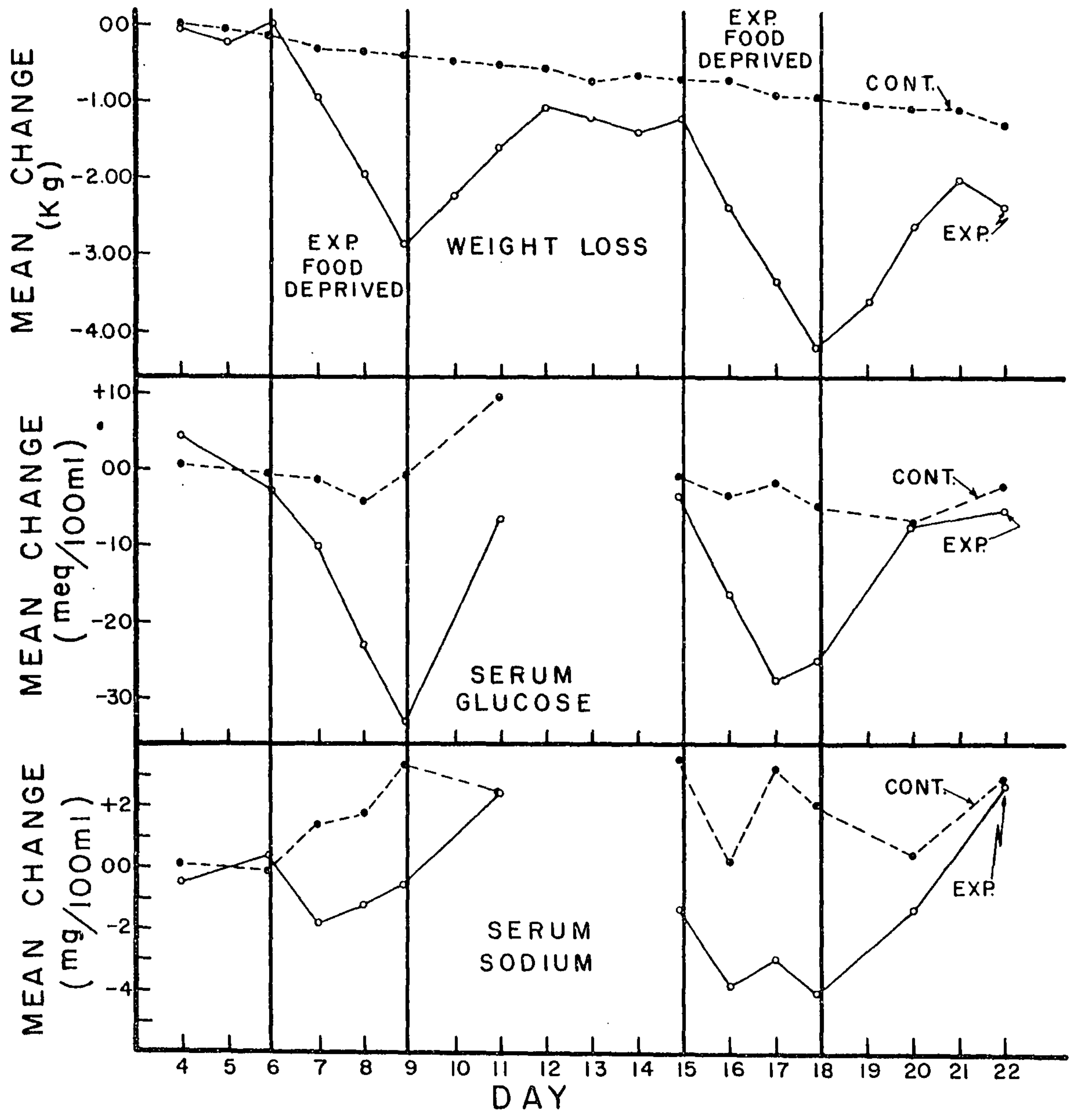

Fig. 8. Body weight, serum glucose and serum sodium change as a function of feeding and deprivation schedule.

Table 26

Summary of Analysis of Variance of Change in Body Weight

Source	df	MS	F
Between	8		
Group (A)	1	18.817	7.15*
Error (a)	7	2.630	
Within	45		
Feeding Schedule (B)	2	4.867	56.00**
A X B	2	2.880	33.14**
Error (b)	14	.087	
Replication (C)	1	8.725	17.05**
A X C	1	1.211	2.37
Error (c)	7	.512	
B X C	2	.059	1.79
A X B X C	2	.047	1.43
Error (b X c)	14	.033	
Total	53		

*Significant at .05 level.

**Significant at .01 level.

dep periods. The Cont. group curve on the other hand, appears relatively stable except for a sharp increase on Day 11. The significant group X feeding schedule interaction (Table 27) supports the differential response of Exp. and Cont. groups across the feeding schedule seen in Fig. 8. The significant group X replication interaction indicates that the Cont. group's glucose level dropped at a faster rate, from original to replication, than did that of the Exp. group. This effect is probably due to the unaccountable rise in the Cont. group's glucose level on Day 11.

While the graph of serum sodium results (Fig. 8) shows apparent separation between the groups in Dep 1 and Dep 2, the only significant $\underline{F}$ ratio is the group X replication interaction (Table 28) indicating that the rate of decrease from original to replication is greater for the Exp. group.

The graph of the urine sodium change (Fig. 9) shows distinct differences in group levels. The Exp. group's sodium level drops sharply during Dep 1 and Dep 2 followed by recovery during the Post-dep periods. The Cont. group curve remains relatively stable throughout. The group X feeding schedule interaction indicates that the differential effects of feeding schedule on groups is significant (Table 29) while the nonsignificant group X replication interaction indicates that the rate of change from original to replication is essentially the same for Exp. and Cont. groups.

The graph of urine potassium mean change (Fig. 9) shows the same overall trends as the urine sodium despite the greater variability of both groups. The results of the analysis are also similar to the extent that group X feeding schedule interaction, but not the group X replication interaction, is significant (Table 30).

Table 27

Summary of Analysis of Variance of Change

in Serum Glucose

Source	df	MS	F
Between	8		
Group (A)	1	1340.08	10.65*
Error (a)	7	125.80	
Within	45		
Feeding Schedule (B)	2	659.46	20.12**
A X B	2	384.39	11.73**
Error (b)	14	32.77	
Replication (C)	1	182.79	20.55**
A X C	1	51.27	5.76*
Error (c)	7	8.90	
B X C	2	58.88	3.69
A X B X C	2	98.46	6.17*
Error (b X c)	14	15.95	
Total	53		

*Significant at .05 level.

**Significant at .01 level.

Table 28

Summary of Analysis of Variance of Change

in Serum Sodium

Source	df	MS	F
Between	8		
Group (A)	1	83.76	2.75
Error (a)	7	30.45	
Within	45		
Feeding Schedule (B)	2	19.28	2.02
A X B	2	13.38	1.40
Error (b)	14	9.55	
Replication (C)	1	1.37	.59
A X C	1	24.12	10.36*
Error (c)	7	2.33	
B X C	2	9.37	1.46
A X B X C	2	3.88	.60
Error (b X c)	14	6.44	
Total	53		

*Significant at .05 level.

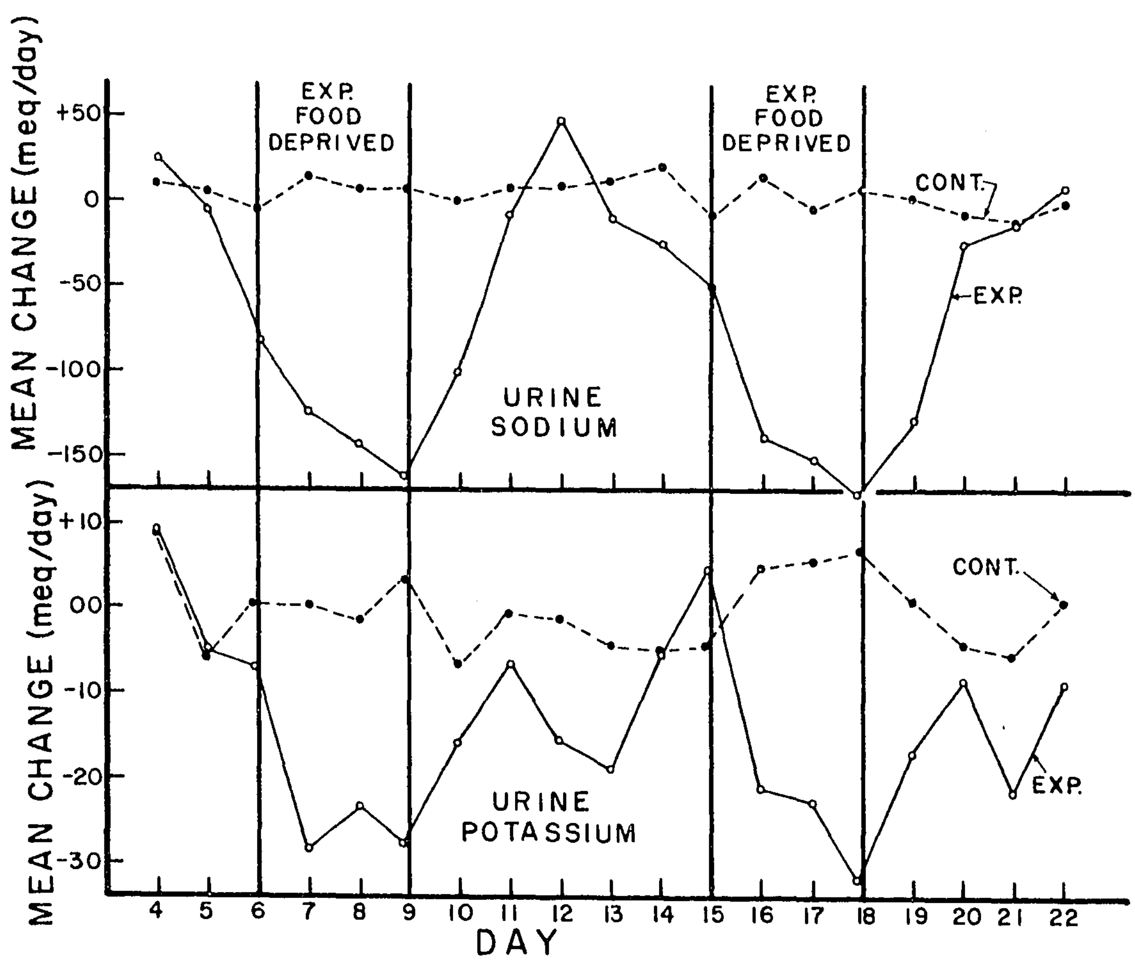

Fig. 9. Urine sodium and potassium change as a function of feeding and deprivation schedule.

Table 29

Summary of Analysis of Variance of Change

in Urine Sodium

Source	df	MS	F
Between	8		
Group (A)	1	345.75	16.09**
Error (a)	7	21.48	
Within	45		
Feeding Schedule (B)	2	104.35	28.98**
A X B	2	119.59	33.21**
Error (b)	14	3.60	
Replication (C)	1	.18	.02
A X C	1	.34	.03
Error (c)	7	9.82	
B X C	2	6.21	1.33
A X B X C	2	5.81	1.25
Error (b X c)	14	4.66	
Total	53		

**Significant at .01 level.

Table 30

Summary of Analysis of Variance of Change

in Urine Potassium

Source	df	MS	F
Between	8		
Group (A)	1	1934.65	2.92
Error (a)	7	662.27	
Within	45		
Feeding Schedule (B)	2	75.82	1.11
A X B	2	360.42	5.28*
Error (b)	14	68.27	
Replication (C)	1	47.57	.71
A X C	1	17.73	.26
Error (c)	7	66.97	
B X C	2	146.93	2.49
A X B X C	2	24.61	.42
Error (b X c)	14	58.91	
Total	53		

*Significant at .05 level.

Overall, the body weight, blood and urine analysis results show the expected decreases with hours of deprivation. There is little evidence of adaptation occurring during Dep 2 with measures of body weight and serum sodium actually showing greater decreases in Dep 2 than in Dep 1. Furthermore, none of the above measures seem to follow closely the course of the visual threshold or inhibition matching curves.

Experiment V - Hunger and fatigue scales

In Fig. 10, the median hunger and fatigue scale ratings are graphed. The graph shows that the median hunger and fatigue rating for the Exp. group rises during Dep 1 and Dep 2 and returns to Pre-dep levels during the Post-dep periods. Mann Whitney U tests computed to test the difference between groups at Day 9 (am) and Day 19 (am) for both hunger and fatigue were found to be significant ($p < .05$).

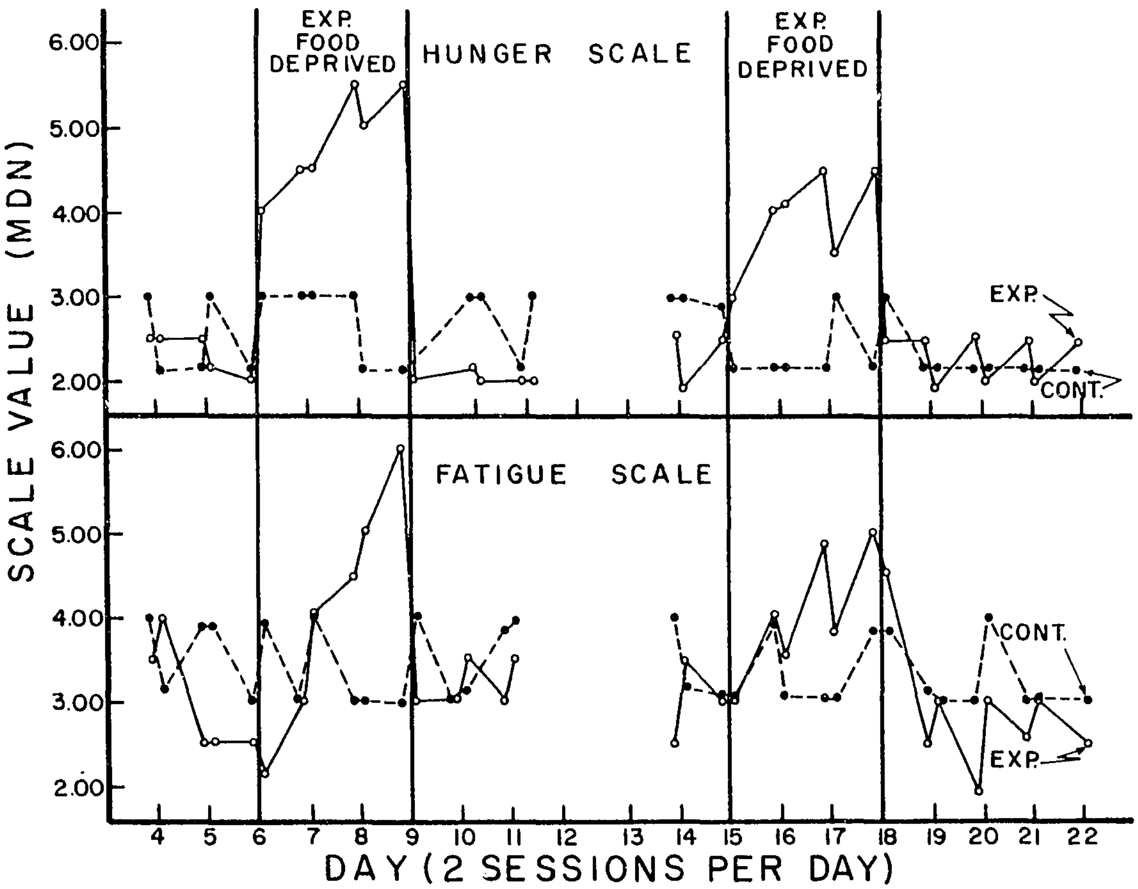

Fig. 10. Hunger and fatigue rating change as a function of feeding and deprivation schedule.

CHAPTER IV

DISCUSSION

Visual responding

The threshold and inhibition results clearly show differences between the groups across the feeding and deprivation schedule. However, the point at which separation occurred and the direction of the difference was completely unexpected. The fact that thresholds of both groups dropped (increased sensitivity) during Pre-dep 1 and Dep 1 suggests that variables other than food deprivation were also affecting visual sensitivity. While there is no direct indication of the nature of these non-deprivation variables in the present study, it is evident that neither the measures of internal states of the S nor the measures of subjective ratings of hunger and fatigue are directly related to such variables. That is, none of the internal states or subjective measures vary systematically with the threshold changes across the entire experimental schedule.

Since the results suggest the presence of variables other than food deprivation, it would seem that a discussion of alternative explanations of the visual data is in order.

One explanation of the change in sensitivity shown by both groups up to Day 9 (am) is that the change occurred as a result of practice. There is, however, little evidence to support a practice effect as the cause of change. First, all Ss were well practiced on the visual task, having had at least six training sessions prior to the beginning of Pre-dep 1. The pre-experimental training sessions consisted of instructions and procedures to train Ss to (a) establish a stable criterion for making judgments which would be consistent between sessions, and (b) to reduce variability within an experimental session. Previous experience had shown that this could be accomplished in three to four training sessions with little subsequent change in either absolute level of response between sessions or variability within sessions. An examination of Ss' within session variances shows no systematic reduction through Day 9 (am) such as one would expect to find if performance was improving with practice. Furthermore, if it is assumed that the results are attributable to practice, then one would be hardpressed to account for the separation between Exp. and Cont. curves from Day 9 (pm) on. Lastly, three to six experimental sessions conducted 30 days following completion of the present study on the four Exp. Ss and three of the five Cont. Ss showed the absolute threshold level of the Exp. group to be essentially the same (0.01 log mL. difference) as the mean of their Day 4 (am) level. This would support the contention that the Exp. group's threshold level, independent of extraneous variables operating during the Pre-dep 1 period, was not significantly different than the Day 4 (am) threshold level and that practice effects would not account for the subsequent drop in threshold. The post session mean for the Cont. group, although not as reliable because only three of the five Ss were available, does not agree with the Exp. group results since the post-session mean of the Cont. group was -0.20 log mL below its Day 4 (am) level. Possible reasons for this difference are discussed below.

Despite the above argument, practice cannot be completely ruled out as an explanation of the visual data during Pre-dep 1 and Dep 1. The conditions of the present study might have been such that practice was affecting performance during the first nine days. Thus, it can only be concluded that variables other than hours of food deprivation were affecting visual responding and that from Day 9 (pm) on, such variables were affecting Exp. and Cont. groups differentially.

A second possible explanation of the change in sensitivity shown by both groups through Day 9 (am) is that the apparatus was changing systematically during this period. The usual precautions concerning calibration, however, were taken, i.e., the apparatus and the calibrating device, were calibrated before all sessions. Also, the notion of a systematic apparatus change does not fit well with the separation of Exp. and Cont. group curves on Day 9 (am).

The third possible explanation which should be considered is that treatment factors other than food deprivation or practice were present throughout the course of the experiment. One might speculate that social isolation, rigid eating schedule, repetitious meals, drawing of blood samples, restriction of physical activities and boredom might result in psychological stress reactions for both Exp. and Cont. Ss. Stimulus deprivation studies have shown that isolation can result in marked changes in perceptual functioning (Heron, Doane, and Scott, 1956). On the other hand, there might also be aspects of the experimental schedule which would be expected to affect the Exp. group relatively more than the Cont. group. Anticipation of discomfort and fear of the dangers resulting from an extended fast could be operating during the Pre-dep 1 period to induce relatively greater stress in the Exp. group. Indirect support for the effects of anticipation on visual sensitivity are found in the work of Diamond (personal communication) where it was found that Ss' visual sensitivity doubled when they were told that if their performance was more exact or less variable than the average of the group, they would receive $4.80 reward.

Evidence for the effects of anticipated noxious stimuli on visual sensitivity are not known to the present author, but anticipation of shock, even though S does not receive the shock, has been shown to result in physiological changes (Jenks and Deane, 1963). In addition, the establishment of a classically conditioned response using noxious stimuli would seem to be based on Ss anticipation of the noxious stimulus.

Thus, it is possible that aspects of the experimental schedule other than food deprivation could be affecting visual sensitivity of both groups while fear and anticipated discomfort were affecting the Exp. group. For the Cont. group, such effects could be cumulative across days since their schedule was relatively unchanging throughout. As stress gradually built up, threshold would decrease across days to some limiting level and remain relatively stable for the remainder of the schedule. In the case of the Exp. group, however, such speculative stress effects would interact with food deprivation. That is, while their gradual onset would be expected during Pre-dep 1, the beginning of food deprivation on Day 6 (pm) would result in a confounding of extraneous stress effects with food deprivation effects. If such an explanation is tenable, it would appear that the resumption of feeding on Day 9 (pm) resulted in a sharp reduction in the combined effects for the Exp. group. During the remainder of the experiment, neither seems to be affecting threshold.

The above explanation is, of course, purely speculative since measures of extraneous variables are not available and a control group which was subjected to neither food deprivation nor the general experimental schedule, was not included in the design. A second control group was not included because of limitations on time and apparatus for gathering data. With only two pieces of visual apparatus, the inclusion of a second control group could have been accomplished only by reducing the number of Ss in the Exp. and Cont. groups or by reducing the number of experimental sessions to one a day. Neither alternative seemed desirable especially in the light of the fact that there was ample data from past research to show the expected course of visual sensitivity over comparatively long periods using untreated Ss. For example, Wertheimer (1955) found no systematic change in threshold for 3 Ss measured repeatedly over a 23 day period. On the basis of Wertheimer's data, the best estimate of a threshold curve across 22 days for untreated Ss appears to be one which is relatively flat with random day-to-day variability of 0.16 log units.

While the above post hoc explanation suggests variables to either be explored or controlled in future research, the main findings of the present study regarding the effects of food deprivation on visual responding are that (a) a food deprived group shows significant differences in visual responding from a control group; (b) the changes in visual responding, only partly accounted for by food deprivation, suggest the presence of other variables; and (c) these changes are not directly related to changes in autonomic measures or to subjective measures of hunger and fatigue.

Regarding the enhancement results, the hypothesis was that both groups would show enhancement on days when they were eating the standard diet, but that under food deprivation the Exp. group would show a loss of enhancement. In the present study, the enhancement effect was not consistently found for either group and therefore could not be shown to disappear with deprivation. It should be noted that in previous research (Heinemann, 1955; Kleman, et al., 1961) the enhancement effect was of small magnitude and that a number of studies have failed to find enhancement under stimulus conditions similar to those of the present study (Cole, 1963). A possible explanation of the failure of enhancement to occur in the present study is suggested by the results of previous research, where it was found that with the administration of caffeine, enhancement was eliminated, amount of depression increased (Kleman, et al., 1961) and threshold decreased (Smith, 1961). Since both groups in the present study showed effects similar to those found by Kleman, et al., and Smith (decreased threshold and increased inhibition) during Pre-dep 1, it is possible that the point at which enhancement would be eliminated had already been reached by Day 3. Such an explanation, of course, implies that uncontrolled variables, such as those discussed above, were operating during Pre-dep 1 to bring about decreased threshold and increased inhibition.

Adaptation to deprivation

Interpretation of the results relating to the hypothesis that adaptation to food deprivation would lead to smaller visual changes in Dep 2 than in Dep 1 is subject to the same difficulties listed above. However, it is evident from Fig. 1 that the amount of decrease in threshold for the Exp. group is less in Dep 2 than in Dep 1. This difference might be due to the adaptation to food deprivation or adaptation to other drive inducing aspects of the experimental regimen. The fact that the Exp. group's curve is relatively stable during Pre-dep 2 suggests that extraneous variables, such as fear and anticipated discomfort, that might have been causing the decrease in their threshold during Pre-dep 1 are evidently not operative in Pre-dep 2. Also, the small decrease in their threshold during Pre-dep 2 (-0.16 log mL.) as compared to Dep 1 (-0.28 log mL.)

suggests that the effects of food deprivation are reduced in Dep 2. Such an interpretation must be regarded as speculative, however, since the effects of deprivation can not be separated from the effects of extraneous variables.

Internal Changes

A third hypothesis of the present study relates to expected changes in internal states of the Ss which are induced by food deprivation and possible relationships between them and visual measures. Regarding the first point, the measures taken by the present author and those taken by Rogers on the same Ss give a fairly comprehensive picture of internal changes that accompany two 72 hour periods of food deprivation separated by five days on a maintenance diet. In general, diastolic BP increases, systolic BP decreases and pulse pressure decreases with hours of food deprivation. In addition, serum glucose and sodium levels, urine sodium and potassium excretion, and body weight decrease with hours of deprivation. There appears to be little evidence from any of these measures of a reduction in amount of change from the original deprivation period to the replication. The failure to demonstrate physiological adaptation to successive periods of deprivation, as found by Taylor et al., (1945) might be due to the shorter recovery period between fasts in the present study (five days vs. five weeks in the Taylor study). The failure of systolic BP and body weight to recover to Pre-dep 1 levels during the recovery period suggests that decremental effects of the first deprivation period were carried over into the second. On the other hand, it may be that a greater number of successive fasts are necessary before adaptation occurs. Taylor et al., present only the first vs. fifth fast comparison in their study.

Regarding the hypothesized relationship between internal states and the visual responses, visual comparison of the threshold graph with the physiological, body weight and chemical measures fails to reveal a single measure in which Exp. and Cont. curves are highly correlated with their respective threshold curves. This result fails to support the notion that there is a direct relationship between internal states induced by food deprivation and concomitant changes in sensitivity as suggested by previous research (Keys et al., 1950; McFarland, et al., 1945; McFarland, et al., 1940). The disagreement might be due to differences in design or to differences in methods used to induce internal changes. For example, in studies where food deprivation was used to induce internal changes, repeated measure designs were used without including a nondeprived control group. Sensitivity and physiological data were gathered at a single pre-deprivation point, at the point of maximum deprivation and at a point during recovery. If, in the present study, only these three points for the Exp. group are considered, then direct relationships between visual sensitivity and a number of measures of internal state would be shown. However, with measures taken at discrete intervals across the schedule, the inclusion of a replication and a nondeprived control group, it is obvious that such relationships fail to hold. McFarland, on the other hand, used either ingestion of strong glucose solutions or insulin injections to raise or lower blood glucose levels. The relationship between visual threshold and blood glucose level was found to be opposite to the findings where food deprivation was used, i.e., threshold level increased as blood glucose level decreased. These findings, when taken in conjunction with the results of the present study suggest that while visual sensitivity and autonomic states may be highly correlated under some conditions, there is no necessary causal relationship between them.

Subjective ratings

The hunger and fatigue scale results, although subject to difficulties of interpretation inherent in any undisguised, subjective scale, show that these psychological attributes of food deprivation tend to vary directly with the feeding and deprivation schedule. Regarding the relationship of hunger and fatigue responses to other response measures, visual inspection shows that they appear to be more highly correlated with measures of internal states than with measures of visual sensitivity. Thus, it appears that if variables other than food deprivation were affecting visual sensitivity, as suggested above, these variables were not affecting subjective ratings of hunger and fatigue in the same manner.

With the small number of subjects used in the present study, large changes in hunger and fatigue ratings would be required to reach significance. However, it is of interest to note relationships in the Exp. group data which were verified by nonquantitative information. In informal question periods held each day, all Ss in the Exp. group reported that their "hunger pangs" had stopped and their "desire for food" had lessened by the afternoon of the second day of fasting in both Dep 1 and Dep 2 even though they still reported having "empty feelings". Fig. 10 shows a reversal in the hunger scale curves at this point in both Dep 1 and Dep 2 although the values remain above Pre-dep levels. Evidently the cessation of hunger pangs alone is not sufficient to cause a reduction in subjective hunger to Pre-dep levels. Feelings of "emptiness" and the knowledge that they need food probably keeps their scale ratings of hunger at a high level until the first meal is eaten.

All Exp. Ss also reported that, in general, the second starvation period was "not as bad" as the first, mentioning that they were "less hungry and tired" during the second. Fig. 10 shows that the highest levels of both hunger and fatigue were reached in Dep 1. For the hunger data, each point during Dep 1 is higher than its comparable point in Dep 2. Even with these consistent differences, a Sign test of differences failed to reach significance ($p = .14$).

Conclusions

The data obtained in this study showed that visual responding of a food deprived group differed significantly from that of a nondeprived group. However, the point in the feeding and deprivation schedule at which the separation between groups occurred and the direction of the difference suggest the presence of other variables of a more psychological nature. There was also evidence that the relationship between visual responding and autonomic measures found in previous research does not hold when a nondeprived control group and a second deprivation period are used. Subjective measures of hunger and fatigue varied directly with hours of food deprivation and therefore, reflected changes in autonomic responding to a greater degree than changes in visual responding.

APPENDIX A

HUNGER SCALE

1. Satiated, not hungry, feel like I have just finished a large meal. ________
2. Not hungry, comfortable, no need to eat at present. ________
3. Slightly hungry, could eat a snack. ________
4. Hungry, normal need for food one feels before regular meal. ________
5. Hungrier than usual before a meal, eagerly looking forward to food as soon as this test is over. ________
6. Very hungry, keep thinking of things I like to eat, real hunger pangs. ________
7. Hungriest I have ever been, can't think of anything but food, can't go much longer without food. ________

FATIGUE SCALE

1. More alert than I have ever felt before. ________
2. Energetic, mobilized, eager to perform. ________
3. Wide awake, ready to perform. ________
4. Awake, relaxed, will perform as necessary. ________
5. Tired, sleepy, need to rest a little, actions slowing down. ________
6. Very sleepy, very tired, feel run down, need a long rest. ________
7. Exhausted, dragging, extremely sleepy, extremely tired, near end of self control. ________

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