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The effects of water deprivation on the body weight, food intake and water intake of the albino rat

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The Effects of Water Deprivation on the Body Weight, Food Intake, and Water Intake of the Albino Rat

by

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INTRODUCTION

A survey of the literature reveals a substantial body of research concerned with the effects of food and/or water deprivation on body weight, food and water intake, and activity of the albino rat. This research is important because many psychological experiments, particularly those studies in the field of animal learning in which motivation is induced by the use of a nutritional maintenance schedule, require some measurement of performance on consecutive days during which the Ss are in a motivational state. Until, and unless, the effects produced by the deprivation schedules themselves are known, and adequate allowance for these effects is made in the experimental procedure, the use of such schedules in learning experiments may make the interpretation of the results difficult. If changes produced by the deprivation schedule occur at the same time that changes produced by the experimental treatment occur, these two sources of variability are confounded.

Most research with maintenance schedules has been concerned with the effects of food deprivation. Many investigators have studied weight loss of the albino rat as a function of food deprivation intervals (Baker, 1955; Ehrenfreund, 1959; Finger, 1951; Finger and Reid, 1952; Finger, Reid, and Weasner, 1957; Kaplan et al, 1959; Lawrence and Mason, 1955; Ramond, Carlton, and McAllister, 1955; Reid and Finger, 1955.) Typically, rats subjected to an extended food deprivation period will lose weight, and this function for 23 hrs. deprivation, i.e., food available one hour every 24 hours, has been empirically determined (Ehrenfreund, 1959; Kaplan et al, 1959; Reid and Finger, 1955.). Also weight loss associated with 21 hr. (Finger, Reid, and Weasner, 1959.) and 22 hr. (Lawrence and Mason, 1955) deprivation has been determined. Longer periods of deprivation have been used (Baker, 1955; Finger, 1951.). In one of these studies (Finger, 1951) the analysis was confined to the effects of a single food deprivation of 72 hrs. Baker maintained 12, 24 and 36 hr. schedules for 40 days. He found that the weight loss of the 12 and 24 hr. groups was comparable, while the 36 hr. group showed a more extended weight loss. The relationship between weight loss and severity of food deprivation is generally assumed to be an increasing monotonic function, but as yet no one has unequivocally demonstrated this function using a wide range of deprivation periods over an extended period of time.

Consummatory behavior in relation to food deprivation has also received experimental attention. Some of the studies mentioned (Baker, 1955; Ehrenfreund, 1959; Lawrence and Mason, 1955; Reid and Finger, 1955.) have studied food intake of food deprived groups. In this respect, the 23 hr. deprivation schedule has received the most attention because it has been a popular deprivation interval in learning studies. When subjected to this schedule, rats tend to increase their food consumption during successive daily 1-hr. feeding periods (Ehrenfreund, 1959; Ghent, 1957; Reid and Finger, 1955.). Baker's study (1955) gives some idea about the relationship between food intake and severity of deprivation. In studying 12, 24 and 36 hr. groups, he found that during deprivation all of the groups increased in amount consumed during the feeding period for the first 10 days; however, for the next 30 days the 24 hr. group averaged highest intake. Bousfield and Elliott (1934) introduced delays in feeding time of 3½, 12, 24, and 48 hrs. and found that longer deprivations were associated with decreases in amount consumed and a slower rate of eating.

Activity, as measured by the standard activity wheel, is known to increase for animals kept on a 23 hr. food deprivation cycle when compared with a control group kept on ad libitum food and water. (Hall, 1955; Hall and Hanford, 1954; Hall et al, 1953.) It is also known that activity subsides when food deprived animals are returned to ad lib. feeding (Finger, 1951; Finger and Reid, 1952; Hall et al, 1953; Reid and Finger, 1955; Wald and Jackson, 1944). Finger (1951) has found activity to be depressed below normal level when food deprived animals are returned to unlimited feeding. He labels this phenomenon the "satiation syndrome" and suggests that this might be a distorting factor in studies where speed of running is measured after termination of periods of food deprivation. Finger and Reid (1952) report that the "satiation syndrome" was more marked after 72 hrs. of either food or water deprivation than after 24 hr. food or water deprivation.

Special attention has been given in a number of the food deprivation studies to the adjustment of animals to the deprivation schedule when the animals are maintained on the schedule for an extended period of time.

The 23 hr. deprivation schedule, because of its widespread usage, has been explored by Reid and Finger (1955, 1957). These investigators have discovered that when the rat is subjected to an extended 23 hr. food deprivation schedule, certain measures which presumably reflect motivational level are found to change for a number of days after the start of the deprivation schedule before they reach stable values. Experiments which require Ss to be at a uniform motivational level from the first day must allow an opportunity for the Ss to adjust to the particular deprivation schedule before the experimental treatment starts or, as pointed out earlier, their results might be contaminated by the fact that the motivational level of the Ss is changing from day to day until adjustment to the schedule is complete.

Reid and Finger (1955, 1957), concerned with this problem, studied the length of time the animal must be kept on a 23 hr. food deprivation schedule before adjustment to this schedule is achieved. In their first study (1955), using body weight, food and water intake, and activity as the measures of adjustment, they conclude that a minimum of 15 days is required before Ss have adjusted to this schedule. At the end of this period most of the adjustment measures approached stable values. One of the measures they employed, activity in the 1-hr. period preceding the daily hour of feeding, failed to reach a stable value after 30 days on the schedule. Their second study (1957), using an improved procedure, found the activity measure reaching a stable value after 15 days deprivation. Hall et al (1953) showed the activity of 23 hr. food deprived animals increased to an asymptote in 12 days. Howood, Carlton, and McAllister (1955), using hooded rats, found stable body weights to be approached by day 11. Moskowitz (1959), using combined food and water deprivation, found that a group allowed to eat for 1 hr. per day reached asymptotic weight loss at day 15, while activity level increased to a stable value in approximately 22 days.

In view of the use of water deprivation as a common source of motivation for rats, it would seem desirable to investigate the effects of the 23 hr. water deprivation schedule over an extended period of time. A search of the literature fails to reveal any study which measures both weight and intake over an extended period of water deprivation. Siegel (1947), exposing rats to a single experience of water deprivation, has determined water intake during a 5-min. interval as a function of length of water deprivations of 2, 6, 12, 24, and 48 hrs. Food was available to the Ss during the deprivation interval. He found water intake to increase as a sigmoid function of severity of deprivation. Siegel also reported the relationship between percentage body weight lost and severity of deprivation to be monotonically increasing with slight negative acceleration. Siegel and Talantis (1950) have presented a replication of Siegel's earlier study, except that food was withheld during water deprivation. Withholding food did not alter the relationship between intake and severity of deprivation; however, each intake measure in Siegel's earlier study was higher than the comparable measure in the replication. Stellar and Hill (1952), using one deprivation experience at deprivation intervals of 6, 12, 18, 24, 36, 48, 72, 96, 120, 144, and 168 hrs. measured water intake during the immediately following 2-hr. period. Food was present during deprivation. They found intake to be a negatively accelerated increasing function of severity of deprivation. Young, Heyer, and Richey (1952), studying water intake of rats subjected to 10 days on a 23 hr. water deprivation schedule, found that 1 hr. intake increased for the first 4 days of deprivation and remained stable for the next 6 days.

There is some suggestion in the literature that a given period of water deprivation may produce a weaker motivational state than a comparable period of food deprivation. Hall (1955) has shown that the increase in activity associated with prolonged 23 hr. food deprivation is much greater than that associated with prolonged 23 hr. water deprivation. When compared to the continued increase in activity from day to day in the food deprived group, the activity level of the water deprived group, although significantly greater than thaf of _ad lib._ control Ss, showed little day-to-day change. On the basis of these differences in activity of the two deprived groups, Hall suggested that food deprivation produces more motivation than comparable water deprivation and that adjustment to water deprivation is more rapid than adjustment to food deprivation. Finger and Reid (1952) have also suggested that thirst may be weaker than hunger. They observed that Ss deprived of either food or water voluntarily reduce their intake of the available substance, water or food respectively, below the level of intake of the available substance shown by Ss that are not deprived of the first substance. In their study, Ss deprived of water for 3 days ate only 34%

of the normal amount, while Ss deprived of food for 3 days drank 85% of the normal amount of water. Thus during the 3 days, the food deprived group is under an almost pure hunger drive, with very little incidental thirst drive from the 15% reduction of water intake, and the water deprived group is under a thirst drive, presumably as strong at any given time as the hunger drive for the food deprived group, and also a strong incidental hunger drive from the 66% reduction in food intake. If thirst is as strong a drive as hunger, it would be expected that the water deprived group would have a stronger total drive because of its stronger incidental drive. However, activity measures taken during the 3 days showed no difference between the two groups. On this basis, Finger and Reid speculate that the basic thirst drive in the water deprived group might be weaker than the basic hunger drive in the food deprived group.

As mentioned earlier, the measures with which the cited studies have been concerned, body weight, intake, and activity, have been used as indicators of motivational level. There has been some disagreement in the literature as to whether these are the most valid measures of motivational state available.

With regard to activity, Campbell and Sheffield (1953) have proposed that motivational states do not affect activity. Rather they suggest that motivational states lower the threshold of sensitivity to external stimulation, and that the frequently observed change in activity that accompanies deprivation is due to this increased sensitivity. They predict little change in activity in motivated Ss if external stimulation is reduced to a minimum. However, it has been shown (Hall, 1955, 1956; Hall and Hanford, 1954) that drive increases activity independently of external stimulation.

Miller (1955-1956, 1956-1957) proposes that food intake measures may have shortcomings as measures of hunger motivation. He notes that, at higher levels of food deprivation, amount of food eaten does not seem to be a valid indicator of degree of hunger induced. Comparing the consumption response with a variety of other measures he found consumption to be sensitive only at the shorter intervals of deprivation; with increasing lengths of deprivation consumption decreases. He suggests that this may be due to limitations on intake imposed by the volume of the stomach or the ability of the organism to handle the consummatory object. However, at least in the case of water deprivation other investigators (Siegel, 1947; Stellar and Hill, 1952) have concluded that water intake is a reasonably valid index of thirst. Stellar and Hill, in particular, conclude that intake meets more of the ideal specifications of a measure of drive than any other measure of the thirst drive. This contention is largely based on the fact that the amount of drinking increases lawfully as a function of the amount of deprivation.

There is little available evidence on the question of whether body weight loss is a valid measure of motivation. Moskowitz (1959) found a correlation of -.99 between percentage normal weight and activity. Ehrenfreund (1959), in studying weight changes associated with an extended 23 hr. deprivation schedule, found a significant correlation between weight loss during each 23 hr. deprivation period and intake of mash food during the feeding hour following the 23 hrs. However, as noted, both the activity measure and the intake measure may themselves be inaccurate indicators of motivation. A systematic study of weight changes produced by a large number of deprivation intervals is needed to see if weight varies lawfully as a function of severity of deprivation. Such a study has not been reported to date.

Whether or not weight, intake, and activity are the best available measures of drive, they provide a convenient way of comparing the effects of food and water deprivation schedules. The present study investigates the adjustment of the rat to an extended 23 hr. water deprivation schedule. Body weight and food and water intake are used as the measures of adjustment.

METHOD

Subjects. The Ss were 24 male albino rats of the Sprague-Dawley strain, 112 days old at the beginning of the habituation phase of the experiment. The Ss had had no prior experimental treatment.

Apparatus. The rats were housed in a small soundproof room. A continuous 24 hr. record showed the room temperature average was 77.1° with a range from 66° to 84°. No attempt was made to measure or control humidity.

The animals were exposed to a natural day-night cycle by outside light coming through the room window. It is known that the day-night cycle affects food and water intake of the rat. This variable has been thoroughly investigated (Gilbert and James, 1956; Siegel and Stuckey, 1947; Stellar and Hill, 1952; Young and Richey, 1952), and it has been established that approximately 75% of the rat's daily consumption of food and water takes place during the dark 12 hours of the day-night cycle. It should be noticed that in the present study measurements of intake were taken in the early morning, which is a low point on the intake cycle. Gilbert and James (1956) have shown that the intake cycle remains even when animals are deprived of water. Therefore, it may be assumed that in this study all Ss were operating on the normal day-night cycle of intake.

Each animal was housed individually in an 11-in. by 11-in. by 8-in. wire-mesh open-bottom cage which was mounted on a metal rack. Newspaper, folded to fit under each cage, was used to catch food particles that fell through the mesh.

A triple-beam balance scale was used to weigh the Ss and the food portions used in the experiment. This scale was accurate to the nearest .1 of a gram. A graduated cylinder with a capacity of 150 ml. was used for all water measurements. The cylinder was graduated in units of 1 ml.; all readings were made at the meniscus and were accurate to the nearest .5 ml. An 8 oz. non-graduated water bottle was mounted on the side of each cage. A control water bottle attached to an empty cage permitted correction of water intake measures for loss due to evaporation and dripping. The experimental diet was Purina Laboratory Chow in pellet form and tap water.

Procedure. When the animals (N = 24) arrived from the supplier they were placed in individual cages and given ad lib. food and water. This preliminary phase lasted for 6 days and was designed to acclimatize the Ss to the experimental situation.

A 7 day habituation phase followed. During this time the Ss were given ad lib. food and water and daily measurements of food intake, water intake, and body weight were obtained for all Ss at 8 A.M. The measurements were later used to determine whether random assignment of Ss to experimental conditions had resulted in groups equal on these measures.

At the conclusion of the habituation phase the Ss were randomly divided into 2 groups of 12 each. Twelve Ss served in the experimental group which was subjected to 23 hr. water deprivation for Phase I of the experiment (days 1-15), and 12 Ss were used in the control group which was given ad lib. food and water for Phase I.

The experimental procedure followed each day consisted of a number of stages. At 8 a.m. room temperature was recorded. Next all Ss were weighed. This constituted the predrinking weight measure. A counter-balanced weighing schedule was used to evenly distribute starting position in the weighing sequence of each S and thus the time between weighing and the 1 hr. drinking period which followed. Old food was removed as each S was weighed, and this food, plus unconsumed food from the papers, was weighed. When this amount was subtracted from the amount put in at the end of the previous day's drinking period, 23 hour food consumption for each S was obtained. The control bottle was measured next. This amount was subtracted from the amount put in at the end of the previous day's drinking period to yield corrections for the 23 hr. water intake measure. At this time an amount was put in the control bottle for the next hour's control. Next, water remaining in the control group bottles was measured. This measure, when subtracted from the amount put in at the end of the previous day's drinking period gives water intake for the preceding 23 hrs. Finally, preweighed food and premeasured water were given to all Ss. The cages were not disturbed for the next hour.

At the end of this hour, the control bottle was measured first thus providing an estimate of water loss during the hour of drinking. The control bottle was refilled for the next 23 hr. period. Then water remaining in all Ss' bottles was measured for the 1 hr. water intake measure. Next, food remaining was measured to give 1 hr. food intake. Then, measured amounts of food and water were put in for the next 23 hr.

intake measures. Food was given to all Ss but water was returned to the Ss in the control group only. Finally, all Ss were weighed using the same rotation schedule used earlier that day. This constituted post-drinking weight.

At the end of day 15 each of the 2 groups was randomly divided into 2 more groups. Half of the 12 Ss in the control group continued on the usual ad lib. schedule, and half were switched to 23 hrs. water deprivation. Half of the 12 Ss in the experimental group continued under this condition, and half were switched to ad lib. These 4 groups of 6 Ss each were used in Phase II of the experiment which extended for days 16-30.

Thus, the experimental design employed is a 2 X 2 factorial design, with Phase I condition (control and experimental) defining one marginal and Phase II condition (control and experimental) defining the other marginal. The design consisted of the following 4 groups with their designations:

1) Control-Control (C-C) ad lib. food and water for the entire 30 day period. (Phase I and Phase II.)

2) Control-Experimental (C-E) ad lib. food and water for Days 1-15 (Phase I); switched to 23 hr. water deprivation for Days 16-30 (Phase II).

3) Experimental-Control (E-C). Twenty-three hour water deprivation for Days 1-15 (Phase I); switched to ad lib. food and water for Days 16-30 (Phase II).

4) Experimental-Experimental (E-E). Twenty-three hour water deprivation for the entire 30 day period. (Phase I and Phase II.)

It should be noted that it is possible to enter into this design for separate analysis the measurements from the three stages of the experiment—habituation phase, Phase I, and Phase II. It should also be noted that in this experiment groups which are initially treated alike are subsequently subjected to different treatments. For example, all groups are treated alike during the habituation phase. Further the two control groups, treated alike during Phase I, are treated differently in Phase II (i.e. one group remains under control conditions, while the other is changed to experimental conditions). Finally the two experimental groups are treated alike in Phase I and differently in Phase II. In order to make unambiguous statements about the effects of different treatments on groups previously treated alike, it is to be hoped that no differences on any of the measures used will be found between these groups during the period when they are treated alike.

RESULTS

Analyses of variance were applied to body weight, 24 hr. food consumption, and 24 hr. water consumption of the 4 groups during the habituation phase. The results of the analyses appear in Tables 1, 2, and 3. It will be noted that for body weight (Table 1), food intake (Table 2), and water intake (Table 3) it was possible in all cases to retain the hypothesis that there are no differences among the groups during the habituation phase.

Predrinking and Postdrinking Body Weight. The basic data are presented in Figs. 1 and 2. Each point on the graph represents the daily mean of the 6 Ss in each group. The first points in Fig. 1 represent the mean weight of each group on the last day of habituation. The analyses of variance for these data are presented in Tables 4 and 5. Table 4 shows that 23 hr. water deprivation produces a significant reduction in predrinking weight ($P < .001$) for Days 1-15. The hypothesis that the groups belonging to the same treatment condition during this period are equal, i.e., C-C = C-E and E-C = E-E, may be retained ($F = .43$). For Days 16-30 the results are essentially the same; water deprivation produces a significant reduction in predrinking weight ($P < .001$). The groups that are switched at Day 15 reach the same level of weight as the corresponding groups under the same Phase II treatment condition. Fig. 1 indicates that E-C and E-E groups reach asymptotic[1] weight loss at Day 3, and thereafter predrinking weight shows a slight gain. The curves tend to parallel

[1] In this section and the following section the terms asymptotic and levels off are used to refer to graphical points beyond which there is no further decrease in the measure described. The terms stable and (point of) adjustment refer to points beyond which the measure shows no additional consistent change.

Table 1

Analysis of Variance of Body Weight
During the Habituation Phase.

Source	df	ss	ms	F	P
Days 1-15 Condition	1	109.13	109.13	<1.0	
Days 16-30 Condition	1	.46	.46	<1.0	
Interaction	1	177.53	177.53	<1.0	
Within	20	4,294.01	214.70		
Total	23	4,581.13			

Table 2

Analysis of Variance of Twenty-four Hour Food Intake During the Habituation Phase.

Source	df	ss	ms	F	P
Days 1-15 Conditions	1	1.95	1.95	<1.0	
Days 16-30 Conditions	1	1.83	1.83	<1.0	
Interaction	1	3.05	3.05	1.04	
Within	20	58.79	2.94		
Total	23	65.62			

Table 3

Analysis of Variance of Twenty-four Hour Water Intake During the Habituation Phase.

Source	df	ss	ms	F	P
Days 1-15 Conditions	1	126.65	126.65	2.36	>.05
Days 16-30 Conditions	1	.11	.11	<1.0	
Interaction	1	23.97	23.97	<1.0	
Within	20	1,074.31	53.72		
Total	23	1,225.04			

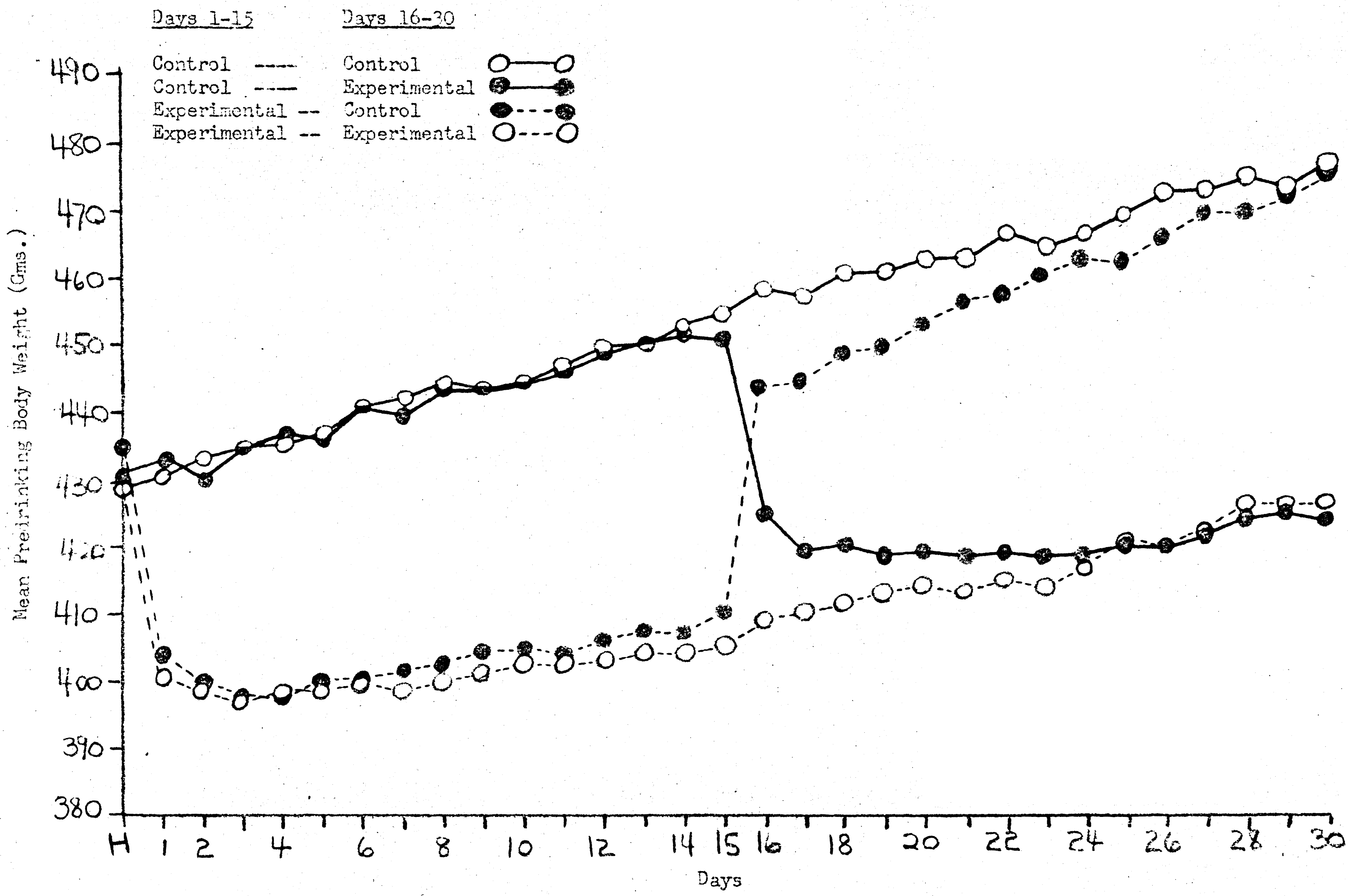

Fig. 1. Mean predrinking body weight of the 4 groups (n= 6 in each) as a function of days.

Table 4

Analysis of Variance of
Predrinking Body Weight.

		Days 1-15 (Phase I)				Days 16-30 (Phase II)			
Source	df	ss	ms	F	P	ss	ms	F	P
Days 1-15 Conditions	1	9,733.26	9,733.26	36.73	<.001	158.52	158.52	.46	
Days 16-30 Conditions	1	11.43	11.43	.43		11,494.87	11,494.87	33.43	<.001
Interaction	1	4.41	4.41	.02		26.38	26.38	.08	
Within	20	5,300.41	265.02			6,876.40	343.82		
Total	23	15,049.51				18,556.17			

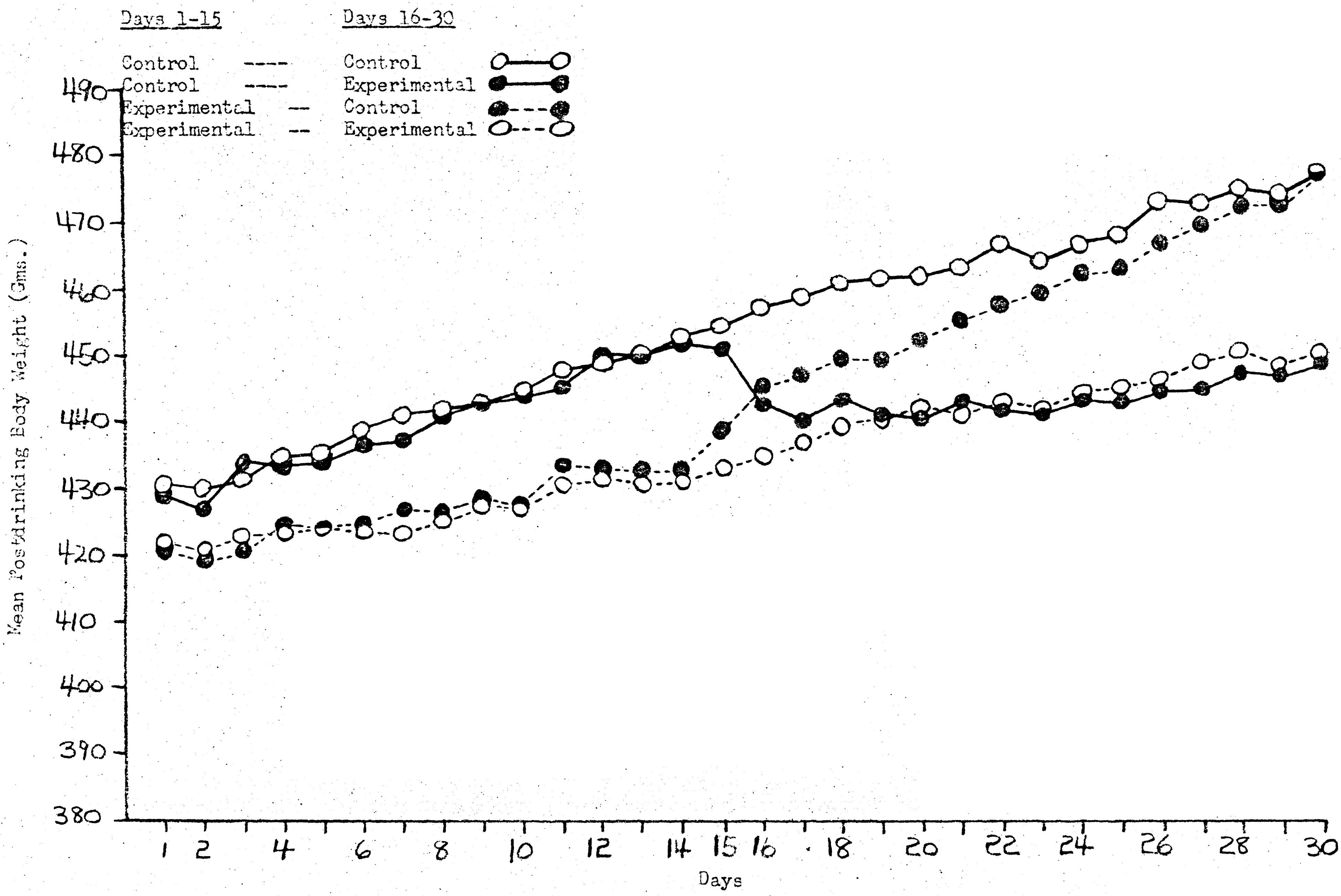

Fig. 2. Mean postdrinking body weight of the 4 groups for days 1-15 and 16-30.

Table 5

Analysis of Variance of
Postdrinking Body Weight.

		Days 1-15				Days 16-30			
Source	df	ss	ms	F	P	ss	ms	F	P
Days 1-15 Conditions	1	1,183.16	1,183.16	4.16	>.05	64.20	64.20	.18	
Days 16-30 Conditions	1	8.65	8.65	.03		2,301.63	2,301.63	6.61	<.025
Interaction	1	.05	.05	.0002		68.37	68.37	.20	
Within	20	5,683.39	284.17			6,961.25	348.06		
Total	23	6,875.25				9,395.45			

those of the control groups. The C-E group, which is switched at Day 15 to the water deprivation schedule, reaches maximum weight loss at Day 4, and the curve remains stable for most of the remainder of the period.

Table 5 shows that there is no significant effect of 23 hr. water deprivation on postdrinking weight for the first 15 days ($F > .05$). This effect is significant, however, at the .025 level for the last 15 days. This effect may be partly seen from Fig. 3 where the difference in postdrinking weights of two of the groups involved in this analysis, the C-C group and E-E group, is plotted for the 30 day period. Fig. 3 indicates that this difference gets larger as the experiment continues, with the largest differences being at Days 16-30. Fig. 3 also presents the differences in predrinking weights of the C-C and E-E groups.

Again, Table 5 shows that no differences were found between groups belonging to the same treatment condition during either Phase I or Phase II. An examination of the curves in Fig. 2 reveals that the postdrinking weight of the deprived groups levels off after 2 days. This is true for both E-E and E-C groups, and the C-E group changed to water deprivation after 15 days.

Differences were computed between each day's predrinking weight and postdrinking weight for each S in each group. This measure represents weight gain or loss for each S during the 1 hour drinking period and is shown graphically in Fig. 4. The corresponding analysis of variance is found in Table 6. It is readily apparent that deprived groups gained more weight during this hour than did the control groups. This difference

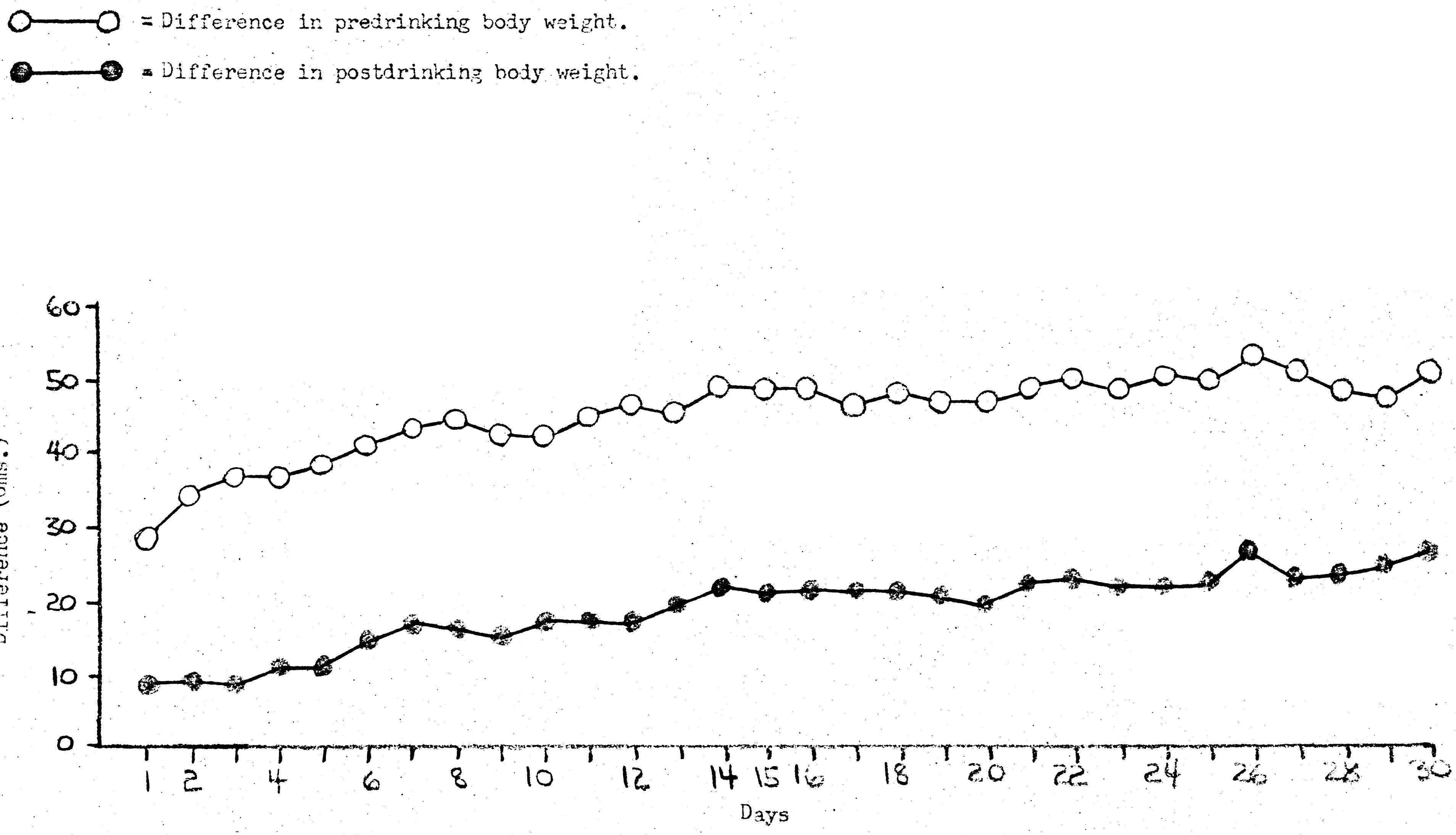

Fig. 3. The difference between the postdrinking weights of the C-C group and the E-E group and the predrinking weights of the same two groups for the 30 day period.

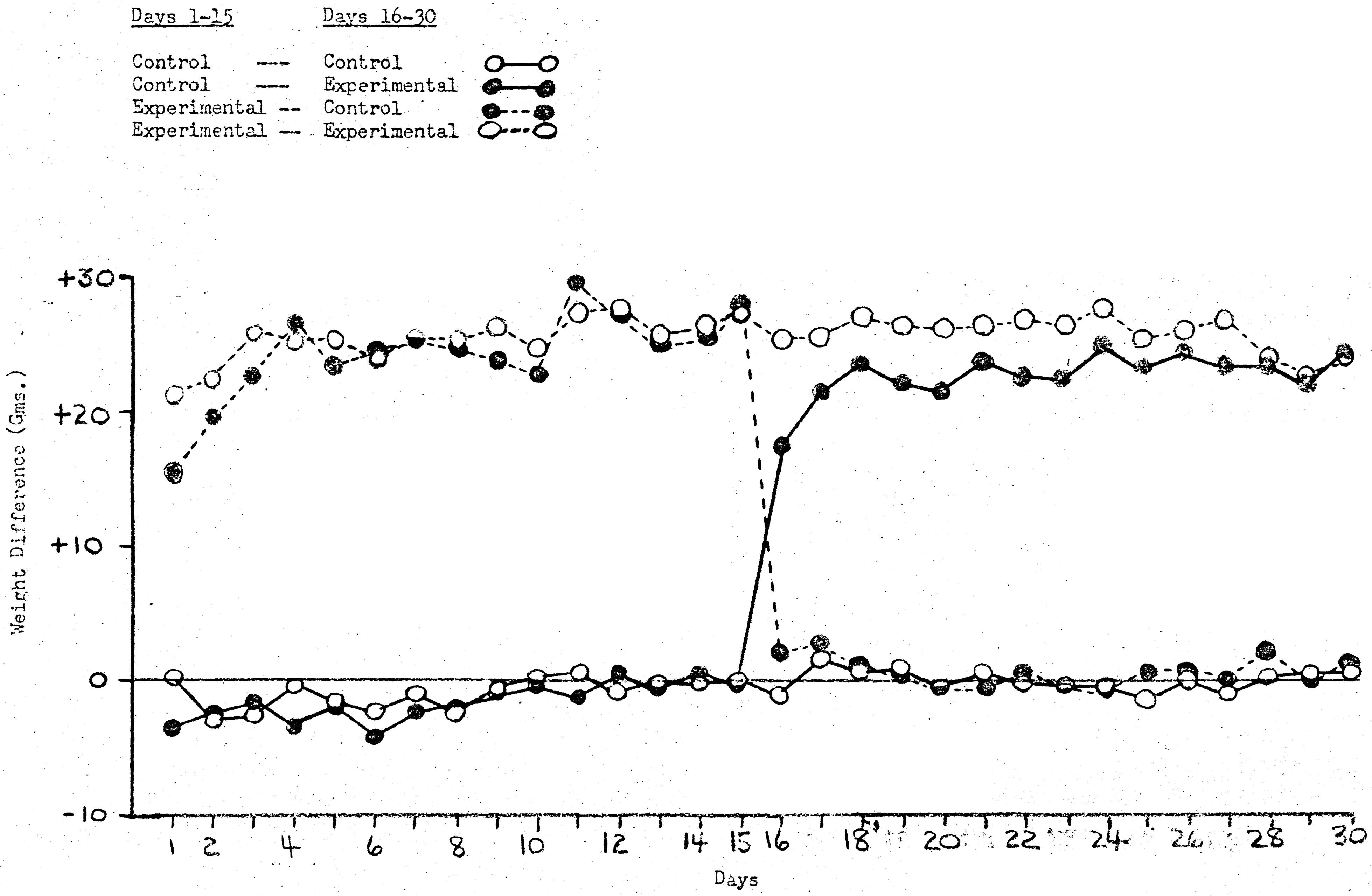

Fig. 4. Postdrinking weight minus predrinking weight of all groups for the 30 day period.

Table 6

Analysis of Variance of
One Hour Weight Gains.

		Days 1-15				Days 16-30			
Source	df	ss	ms	F	P	ss	ms	F	P
Days 1-15 Conditions	1	4,137.87	4,137.87	874.81	<.001	19.58	19.58	2.76	>.05
Days 16-30 Conditions	1	.18	.18	.04		3,503.88	3,503.88	494.90	<.001
Interaction	1	3.57	3.57	.75		10.28	10.28	1.45	
Within	20	94.53	4.73			141.71	7.08		
Total	23	4,235.97				3,675.44			

was found to be significant ($P < .001$) for both Days 1-15 ($F = 874.81$) and Days 16-30 ($F = 494.93$). It may be seen in Fig. 4 that the E-E and E-C groups approach stable weight gain values at Day 4. When switched to 23 hr. water deprivation, the C-E group reaches a stable recovery value by the 3rd day. The two control groups apparently lose weight during the hour for the first 10 days.

Water Intake. Data for 1 hr. water intake for all groups are presented in Fig. 5, and the accompanying analysis is found in Table 7. Control bottle corrections were applied to all water intake measures. All deprivation groups drank more during the hour than the non-deprived groups. This difference is significant beyond the .001 level for Days 1-15 and Days 16-30.

Fig. 5 shows that the E-C and E-E groups reach a stable level of 1 hr. intake at approximately Day 4. Intake of the C-E group reaches a maximum value after the 3rd day of deprivation (Day 18) in Phase II (Days 16-30). The E-C group, when returned to ad lib. food and water shows little tendency to drink larger amounts of water during this hour than the appropriate control group.

Twenty-three hour water intake is presented for 3 groups in Fig. 6. No curve could be presented, of course, for the E-E group. The C-C and C-E groups during Days 1-15 are not different on this measure ($t = .25$, $df = 10$, $P > .09$); however, the difference between E-C and C-C groups on Days 16-30 is large enough to permit the rejection of the hypothesis of equality ($t = 2.25$, $df = 10$, $P < .05$). Fig. 6 shows that the E-C group drinks more than the control group during the 23 hr. period when returned to ad lib. water for Days 16-30.

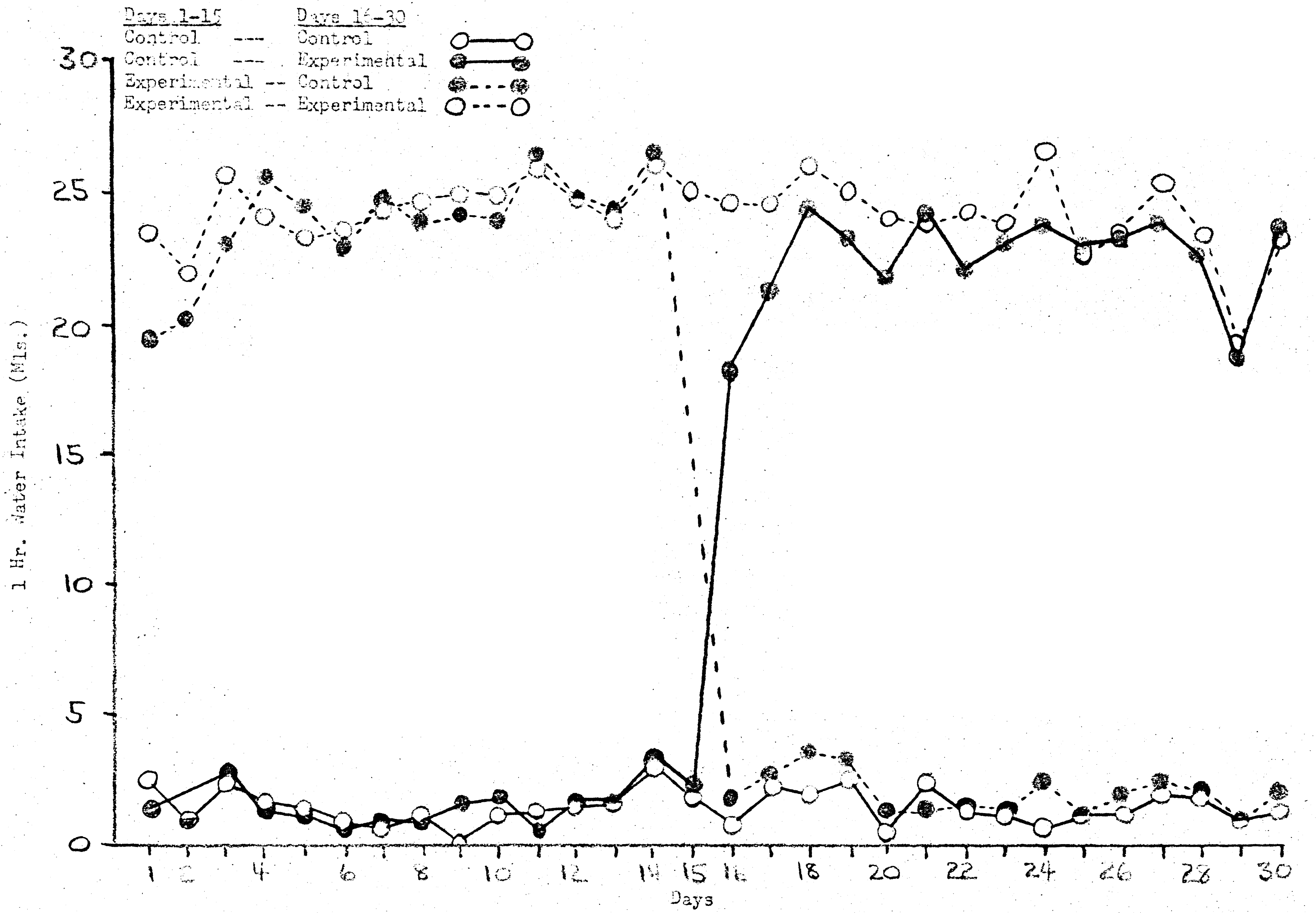

Fig. 5. One hour intake of the 4 groups for the 30 day period.

Table 7

Analysis of variance of
One Hour Water Intake.

		Days 1-15				Days 16-30			
Source	df	ss	ms	F	P	ss	ms	F	P
Days 1-15 Conditions	1	3,081.15	3,081.15	1,339.63	<.001	5.70	5.70	1.70	
Days 16-30 Conditions	1	.31	.31	.13		2,779.98	2,779.98	829.84	<.001
Interaction	1	.19	.19	.08		1.38	1.38	.41	
Within	20	45.93	2.30			67.07	3.35		
Total	23	3,127.58				2,854.13			

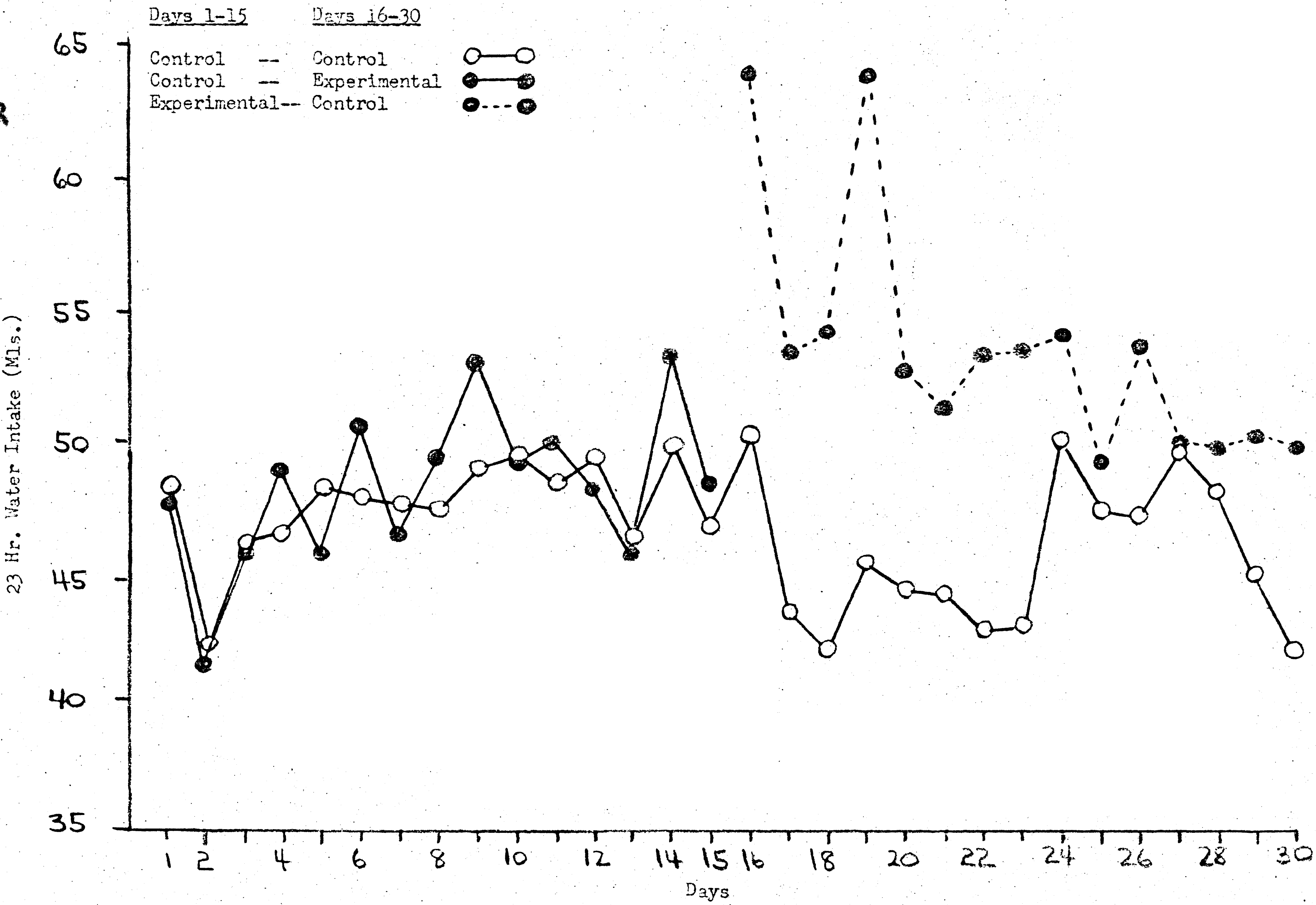

Fig. 6. Twenty-three hour water intake of 3 groups as a function of days.

Food Intake. One hour food intake is presented in Fig. 7 for all groups, and the corresponding analysis is found in Table 8. The experimental groups which have water only during this hour each day show significant superiority ($P < .001$) in food intake during the hour for both Days 1-15 and Days 16-30.

Twenty-three hour food intake is presented in Fig. 8 and the analysis of variance in Table 9. Twenty-three hour water deprivation produces a significant reduction in 23 hr. food intake. This effect is significant for Days 1-15 ($F = 203.81$) and Days 16-30 ($F = 162.89$). Another interesting finding is that the C-E group, when placed under the experimental condition, eats less than the group that has had 15 prior days under the experimental condition (Group E-E) and the E-C group, when placed under the control condition eats more than the group that has not had any prior deprivation experience (Group C-C). This finding is shown by the significant effect that Days 1-15 conditions has on the 23 hr. food intake measure for Days 16-30 ($F = 5.94$, $P < .05$) and may be seen in Fig. 8. Further discussion of the use of the present design to determine the effects of early conditions on measures obtained at a later time after the early conditions have been changed may be found in Spence (1953, 1956).

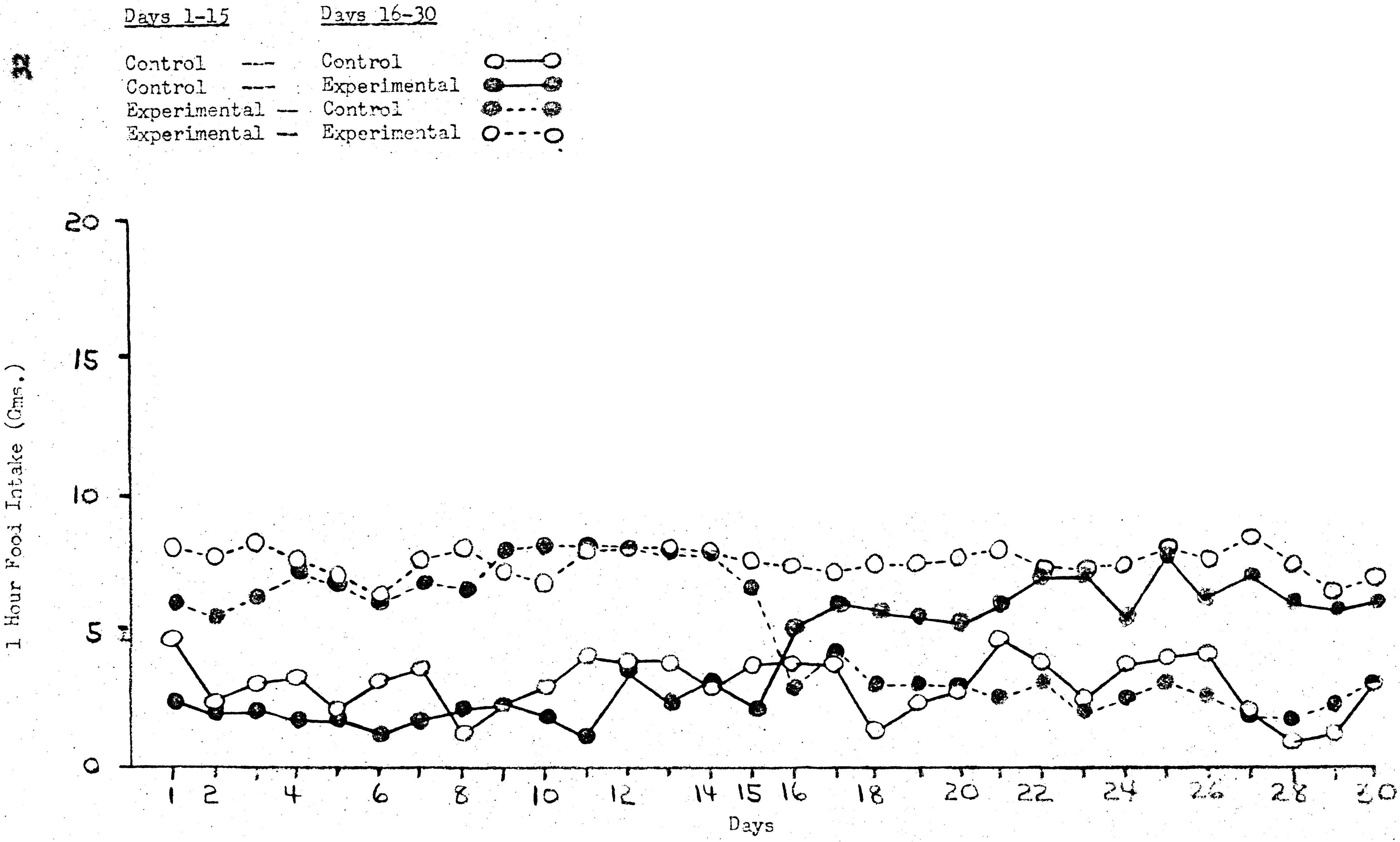

Fig. 7. One hour food intake of the 4 groups for the 30 day period.

Table 6

Analysis of Variance of
One Hour Food Consumption.

		Days 1-15				Days 16-30			
Source	df	ss	ms	F	P	ss	ms	F	P
Days 1-15 Conditions	1	155.59	155.59	85.96	$<.001$	3.60	3.60	2.59	$>.05$
Days 16-30 Conditions	1	.03	.03	.02		104.70	104.70	75.32	$<.001$
Interaction	1	1.69	1.69	.93		2.64	2.64	1.90	$>.05$
Within	20	36.21	1.81			27.85	1.39		
Total	23	193.51				138.79			

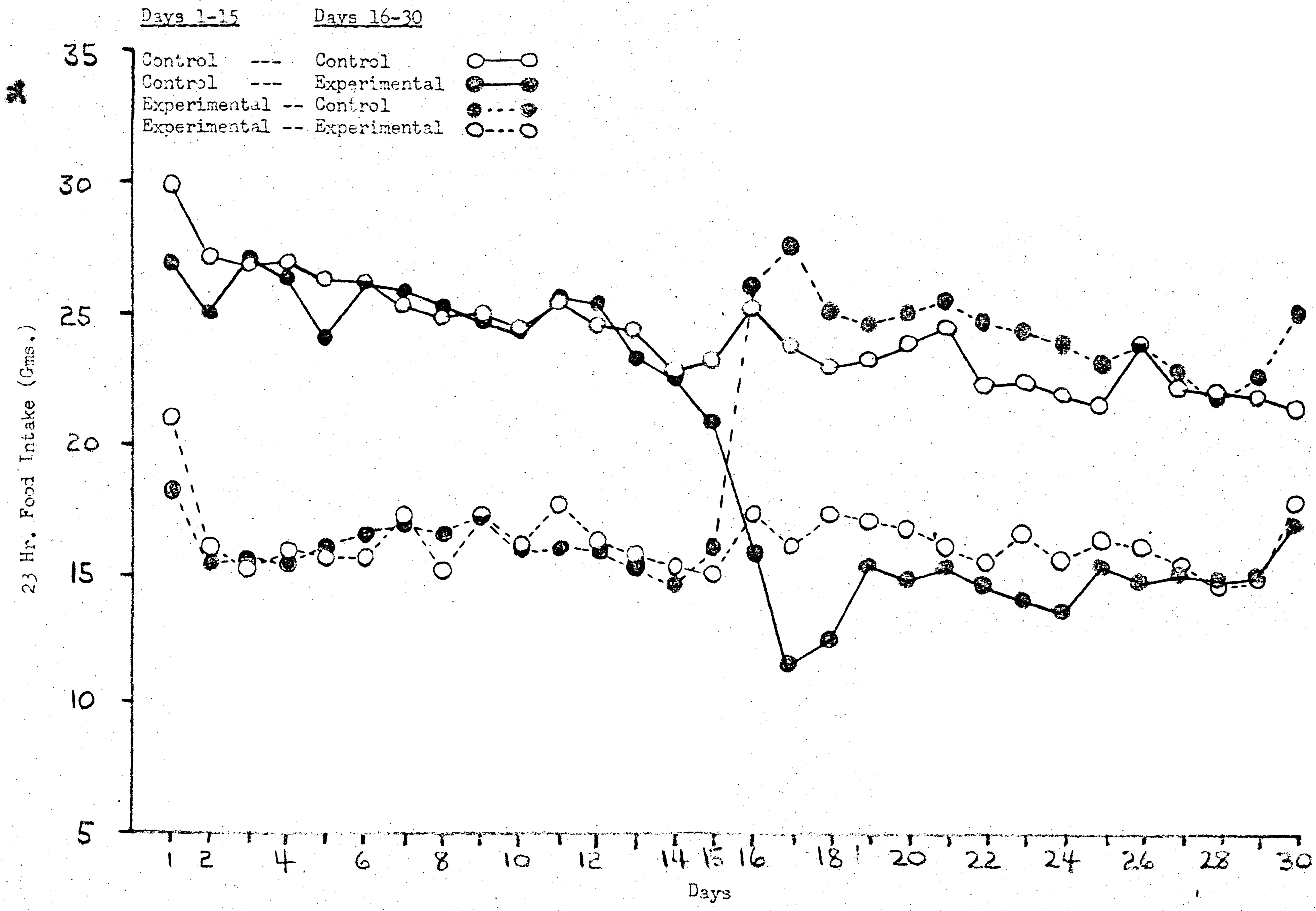

Fig. 8. Twenty-three hour food intake of the 4 groups for the 30 day period.

Table 9

Analysis of Variance of
Twenty-three Hour Food Intake.

		Days 1-15				Days 16-30			
Source	df	ss	ms	F	P	ss	ms	F	P
Days 1-15 Conditions	1	487.11	487.11	203.81	<.001	13.73	13.73	5.54	<.05
Days 16-30 Conditions	1	.36	.36	.15		403.95	403.95	162.88	<.001
Interaction	1	1.13	1.13	.47		.02	.02	.008	
Within	20	47.73	2.39			49.55	2.48		
Total	23	536.33				467.24			

DISCUSSION

The results show that one consequence of 23 hr. water deprivation is a loss of body weight relative to an *ad lib.* control group when predrinking weight is used as the measure. This result is consistent with studies that have employed a comparable level of food deprivation and measured prefeeding weight. The largest drop in predrinking weight occurs during the first few days of deprivation.

Significant differences in postdrinking weight did not occur until Phase II of the experiment. For the first 15 days the water deprived groups are evidently consuming enough during the drinking hour so that at the end of this hour their weights are comparable to those of the *ad lib.* control groups. The fact that a difference does occur during the last 15 days suggests a differential rate of weight again for the control and experimental groups. Both groups are gaining weight after the initial drop in weight of the experimental groups. However, Figs. 1 and 2 show that the weight curves tend to diverge, and the progressive separation of these curves reflects a higher rate of gain by the control groups. The divergence of the curves is also seen in Fig. 3 which presents difference measures for the C-C and E-E groups. Although, initially, the experimental groups' intake during the drinking hour is sufficient to raise their postdrinking weight to a level comparable to the controls, the higher rate of weight gain in the control groups eventually produces significant separation of the postdrinking weights in Phase II.

With regard to the intake measures this study presents further evidence on the interrelationship of food and water consumption. Twenty-three hour food consumption of the water deprived groups is significantly less than that of the control groups; apparently water deprivation produces an incidental hunger drive. In this connection, Verplank and Hayes (1953) found that water deprivation produced a 40% "self-imposed" reduction of normal food intake.

As expected, one hour water intake is significantly greater for the experimental groups than the control groups, since this is the only time during the day that experimental Ss receive water. Correspondingly, one hour food intake is also greater for the experimental groups. With water present during this hour, the experimental groups did not show the "self-imposed" food intake reduction and their accumulated hunger over the preceding 23 hours results in greater one hour food intake.

The recovery functions, in Phase II (Days 16-30), of the E-C groups for the 23 hr. food and water intake measures show tendencies to overdrink and overeat relative to the C-C group following the 15 day deprivation period in Phase I. This finding has been reported by several investigators for food deprivation. Lawrence and Mason (1955) found a marked tendency for Ss to overeat when returned to ad lib. food and water after 61 days of 22 hr. food deprivation. Reid and Finger (1955) show food intake during recovery after 35 days of 23 hr. food deprivation to exceed the normal control level for at least 11 days. They also found water intake of the deprived groups to exceed the normal level during 11 days of recovery.

With respect to the principal objective of this study, the results appear to indicate that adjustment to a 23 hr. water deprivation schedule requires a relatively short period of time. In general, in terms of the weight and intake measures, adjustment to as 23 hr. food deprivation schedule requires a more prolonged period of time then adjustment to the comparable water deprivation schedule.

Reid and Finger (1955), employing a standard 23 hr. food deprivation schedule, found that weight reached a reasonably stable level at Day 15. Hamond, Carlton, and McAllister (1955), who allowed hooded rats to eat for 50 min. per day, found prefeeding weight to level off at Day 11. Ehrenfreund (1959) found the prefeeding weight of 23 hr. food deprived Ss to level off at approximately Day 8. Using the same deprivation schedule, Moskowitz (1959), found that body weight reached its lowest limit at Day 15, and then leveled off. In the present experiment both predrinking and post-drinking weight measures indicate that adjustment to a 23 hr. water deprivation schedule occurs within 4 days.

Food intake during the 1-hr. feeding period of 23 hr. food deprived Ss, as shown by Reid and Finger (1955), was found to level off at Day 20. Ehrenfreund's (1959) 23 hr. deprived group increased in their 1-hr. consumption of mash for 25 days. In the present experiment, one hour water intake of the 23 hr. water deprived groups reached stable values after 4 days. Consumption of the non-deprivation object (food) during the 1-hr. period for the E-E and E-C groups was an average, at a relatively stable level from Day 1 on, although in Phase II the C-E group did show a somewhat more prolonged increase on this measure.

The results of studies which use only a single deprivation experience instead of a prolonged period of deprivation cannot be used in comparison with the present study since they provide no data on adjustment to deprivation schedules. However, it is possible to compare the present experiment with experiments on adjustment that have used lengths of food deprivation slightly different from the 23 hr. schedule. These studies also show that a prolonged period of adjustment is required for food deprivation schedules. Baker (1955), using very young animals (the youngest Ss were only 60 days old), found body weight of 12 hr. and 24 hr. food deprived Ss to decrease for only the first 3 days. The weight of a 36 hr. deprived group continued to decline for 18 days. Intake per feeding period increased for his experimental groups for at least 10 days. Baker concludes that a relatively slow adjustment to the deprivation schedule was shown by all groups. Lawrence and Mason (1955) found the daily 2-hr. intake of 22 hr. food deprived Ss to gradually increase to a stable value during the first 12-14 days. The weight curves for their Ss declined to a stable value after 13 days.

Turning to the few available studies of adjustment to a 23 hr. water deprivation schedule, Young, Heyer, and Richey (1952) found weight gain during the one hour of drinking to reach a stable value at Day 4, and 1-hr. water intake to level off after the 4th day. The present study also found both of these measures to reach stable values at Day 4. Although this measure was not used in the present study, activity wheel measures have also indicated that adjustment to water deprivation is more rapid than to comparable food deprivation. Hall (1955) found a stable activity level from Day 1 for water deprived Ss, while the 23 hr. food deprived Ss increased in activity for approximately 15 days.

On the basis of these comparisons between the present results and studies of food deprivation it can be tentatively concluded that a 23 hr. water deprivation schedule requires considerably less time for adjustment than a comparable schedule of food deprivation. The rapid adjustment to the 23 hr. water schedule should receive attention from investigators who attempt to control motivational level through the use of a deprivation schedule. It is suggested that methodological complications arising from successive changes in motivational level during the course of an experiment using deprivation of an appetitive substance may be markedly reduced if 23 hr. water deprivation is used and the animals are introduced into the experiment proper after 5 days on the deprivation schedule.

SUMMARY

The purpose of this experiment was to examine the rate of adjustment of the albino rat to a 23 hr. water deprivation schedule. Food and water intake and body weight of animals on a 23 hr. water deprivation schedule were measured over a 30 day period. Four groups of rats, six to a group, were used. The four groups were: ad lib. food and water for 30 days; ad lib. food and water for 15 days, switched to 23 hr. water deprivation for 15 more days; 23 hr. water deprivation for 15 days, switched to ad lib. food and water for 15 more days and 23 hr. water deprivation for 30 days. Measures were taken of predrinking and postdrinking weight, 1 and 23 hr. water intake, and 1 and 23 hr. food intake.

The main findings were:

1. Deprivation produced a significant reduction in predrinking body weight for the 30 day period. There were no differences in postdrinking weight due to deprivation for the first 15 days; however, the differences were significant for Days 16-30. Deprived groups were found to gain significantly more weight during the 1-hr. of drinking than ad lib. groups.

2. One hour water consumption was significantly greater for the 23 hr. deprived Ss. The group switched from deprivation to ad lib. exhibited a significant tendency to overdrink during the final 15 days when the 23 hour water intake measure is considered.

3. One hour food intake was significantly greater for the water deprived Ss. Also, it was shown that these Ss ate significantly less during the 23 hr. periods. The group changed from deprivation to ad lib. demonstrated a tendency to overeat on the 23 hr. intake measure, and the 23 hr. intake of the ad lib. to deprivation group fell below the group on continued deprivation.

4. The results were discussed in terms of adjustment to a 23 hour water deprivation schedule. Five days was found to be a sufficient period for adjustment. This period is shorter than that required for an equivalent food deprivation schedule.

It was suggested that methodological complications arising from prolonged changes in weight and intake characteristic of a 23 hr. food deprivation schedule could be reduced by the use of a 23 hr. water deprivation schedule.

APPENDIX A

Table 10

Predrinking Body Weight Means for all Groups
During Both Phases of the Experiment.

	Control-Control			Control-Experimental			Experimental-Control			Experimental-Experimental	
S	Day 1-15	Days 16-30	S	Day 1-15	Days 16-30	S	Day 1-15	Days 16-30	S	Day 1-15	Days 16-30
3	429.940	449.833	1	431.153	413.673	2	389.003	448.600	4	435.547	447.453
7	450.973	474.053	5	412.667	380.013	6	404.013	469.147	10	401.567	416.820
11	450.573	475.007	9	463.740	439.953	12	415.020	473.633	14	388.667	404.173
15	457.040	488.593	13	456.313	439.607	16	403.660	457.247	18	415.640	437.240
19	436.133	461.333	17	458.500	443.453	20	407.833	460.007	22	379.400	395.247
23	432.313	451.573	21	431.453	408.457	24	400.767	448.340	25	386.213	405.993
$\bar{x}$=	442.829	466.732		442.304	420.859		403.388	459.496		401.172	417.821
S.D.=	11.40	15.13		20.19	24.90		8.58	10.40		21.19	20.01

Table 11

Postdrinking Body Weight Means for all Groups
During Both Phases of the Experiment.

Control-Control			Control-Experimental			Experimental-Control			Experimental-Experimental		
S	Day 1-15	Days 16-30	S	Day 1-15	Days 16-30	S	Day 1-15	Days 16-30	S	Day 1-15	Days 16-30
3	430.693	453.713	1	428.687	439.513	2	415.853	451.200	4	464.030	474.987
7	452.673	475.027	5	410.160	400.487	6	430.333	468.013	10	427.787	442.460
11	445.507	472.087	9	462.420	465.753	12	439.133	473.207	14	412.700	430.633
15	453.033	486.540	13	453.433	462.900	16	426.540	452.707	18	441.100	463.573
19	437.120	460.900	17	460.653	464.627	20	431.193	460.220	22	401.693	418.567
23	432.093	452.300	21	429.107	429.520	24	424.360	455.347	25	412.220	433.273
$\bar{x}$ =	441.853	466.761		440.743	443.800		427.902	460.116		426.610	443.906
S.D.=	9.93	13.43		21.12	25.99		7.78	8.84		22.97	21.38

Table 12

One Wk. Weight Gain Means for all Groups
During Both Phases of the Experiment.

	Control-Control			Control-Experimental			Experimental-Control			Experimental-Experimental	
	Day 1-15	Days 16-30		Day 1-15	Days 16-30		Day 1-15	Days 16-30		Day 1-15	Days 16-30
S			S			S			S		
3	.820	3.747	1	-2.733	25.340	2	26.820	2.600	4	28.533	27.533
7	1.700	.973	5	-2.507	20.473	6	26.187	-.893	10	26.220	25.580
11	-5.067	-2.687	9	-1.320	25.800	12	24.113	-.427	14	24.033	26.460
15	-4.007	-2.053	12	-2.880	23.227	16	22.880	-4.567	18	25.540	26.333
19	.987	-.113	17	2.153	21.173	20	23.360	-.053	22	22.293	23.320
23	-.420	.727	21	-2.260	21.033	24	23.593	7.000	25	26.007	27.280
$\bar{X}$ =	-.998	.112		1.594	22.958		24.492	.610		25.438	26.084
S.D.=	1.91	.97		.56	2.02		1.62	2.73		2.11	1.52

APPENDIX B

Table 13

One Hr. Water Intake Means for all Groups
During Both Phases of the Experiment.

S	Control-Control Day 1-15	Control-Control Days 16-30	S	Control-Experimental Day 1-15	Control-Experimental Days 16-30	S	Experimental-Control Day 1-15	Experimental-Control Days 16-30	S	Experimental-Experimental Day 1-15	Experimental-Experimental Days 16-30
3	3.067	3.733	1	.900	24.467	2	26.733	2.600	4	27.200	25.633
7	1.333	1.700	5	.400	19.533	6	24.833	1.633	10	21.700	21.000
11	.633	.500	9	2.267	24.200	12	22.000	2.133	14	22.567	22.100
15	.600	.533	13	1.433	25.833	16	24.067	.200	18	26.100	26.367
19	1.467	.867	17	3.200	21.600	20	23.033	1.867	22	23.667	23.200
23	1.567	1.833	21	.767	20.800	24	22.900	3.700	25	24.767	25.867
$\bar{X}$ =	1.444	1.528		1.494	22.572		23.928	2.022		24.334	24.028
S.D. =	.90	.28		1.06	2.35		1.49	.57		2.10	2.24

Table 14

Twenty-three Hour Water Consumption for all Groups During Both Phases of the Experiment.

	Control-Control			Control-Experimental		Experimental-Experimental
S	Day 1-15	Days 16-30	S	Day 1-15	S	Days 16-30
3	37.967	34.833	1	44.267	2	52.400
7	42.300	39.500	5	38.900	6	49.700
11	49.833	44.600	9	46.400	12	56.333
15	57.867	53.967	13	60.500	16	59.333
19	43.100	46.133	17	40.900	20	49.400
23	52.600	54.500	21	60.140	24	54.433
$\bar{x}$ =	47.278	45.589		48.518		53.633
S.D. =	7.43	7.79		9.30		3.94

APPENDIX C

Table 15

One Hour Food Intake Means for all Groups
During Both Phases of the Experiment.

	Control-Control			Control-Experimental			Experimental-Control			Experimental-Experimental	
S	Day 1-15	Days 16-30	S	Day 1-15	Days 16-30	S	Day 1-15	Days 16-30	S	Day 1-15	Days 16-30
3	3.740	4.687	1	.823	6.700	2	8.913	3.667	4	8.700	7.707
7	4.073	3.273	5	.620	5.107	6	7.333	1.573	10	8.947	8.647
11	.200	1.000	9	2.293	7.450	12	6.707	3.340	14	7.020	6.927
15	.600	1.320	13	1.507	5.660	16	5.540	.127	18	6.880	6.753
19	2.520	1.993	17	4.720	4.973	20	6.133	2.980	22	6.973	7.747
23	2.960	2.840	21	1.460	6.280	24	6.640	4.093	25	6.547	7.040
$\bar{X}$ =	2.362	2.522		1.902	6.033		6.924	2.630		7.524	7.470
S.D. =	1.77	1.37		1.90	.97		1.16	1.20		1.05	.70

Table 16

Twenty-three Hour Food Consumption Means for all Groups During Both Phases of the Experiment.

Control-Control			Control-Experimental			Experimental-Control			Experimental-Experimental		
S	Day 1-15	Days 16-30	S	Day 1-15	Days 16-30	S	Day 1-15	Days 16-30	S	Day 1-15	Days 16-30
3	23.740	21.547	1	26.073	15.207	2	15.540	24.360	4	18.500	18.593
7	23.247	20.180	5	23.620	13.840	6	16.613	25.120	10	14.313	14.107
11	28.153	24.527	9	26.580	14.573	12	14.353	23.913	14	16.660	16.093
15	26.893	24.487	13	26.440	15.413	16	16.933	27.300	18	17.113	17.913
19	25.633	23.600	17	22.553	15.580	20	17.460	24.160	22	15.807	14.880
23	25.893	23.473	21	24.220	13.680	24	15.987	21.747	25	15.633	16.073
x =	25.593	22.969		24.914	14.716		16.148	24.433		16.338	16.276
S.D. =	1.86	1.74		1.60	.82		1.11	1.80		1.43	1.72

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