The effects of deprivation and post-deprivation on the heart rate of rats

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The heart rate (HR) of male hooded rats was recorded in their individual home cages for three weeks. Then they were deprived of water (Group 1, $N = 6$) or food (Group 2, $N = 10$) up to 96 h. Immediately after the deprivation period water (for Group 1) and food (for Group 2) were placed in their home cages. Under these conditions, HR was recorded. During the deprivation period, the HR of Group 1 increased linearly with the duration of deprivation, and that of Group 2 showed an inverse U-shaped function. During the postdeprivation period, the HR of both groups sharply increased about 10 min after food or water was placed in their cages. These findings suggest that HR is clearly influenced both by deprivation and by consummatory activities.

The bulk of experimental evidence suggests that dehydration caused by the deprivation of water should increase heart rate (HR). An experiment by Bélanger & Feldman (1962) offered evidence of HR changes as a positive monotonic function of the hours of water deprivation. In their study, the HR was recorded while their rats were performing bar-press responses to obtain water. The data, however, show that the HR kept increasing while the number of bar-presses decreased after about 60 h of deprivation. Since there was no similar relationship between the HR changes and the changes in bar-press responses as a function of the hours of deprivation, Bélanger and Feldman concluded that HR was a function of water deprivation and that it was not a function of locomotor activities.

Other investigators, however, do not agree with Bélanger and Feldman's findings. Ducharmé (1966), for example, reports that "... within a normal range, depriving an animal of water cannot per se produce a direct physiological effect leading to an increase in HR and that the conditions of deprivation alone have no appreciable influence on the level of activation as measured by change in HR ... [p. 103]." Eisman (1966) also states that HR does not vary as a function of water deprivation, but that HR changes as a function of consummatory activity.

Our previous study (1968), however, partly supported Bélanger and Feldman's findings and agreed with Malmö's (1962) proposal that HR can be applied to determine appetitionally-based drive. In our study, two experimental groups, one the water-deprivation group and the other the food-deprivation group, were used to determine the characteristics of the HR changes as a function of deprivation. The results for the water-deprivation group showed a positive monotonic relation with the hours of water-deprivation, but the results for the food-deprivation group showed an inverse U-shaped function. From these findings, it was suggested that HR may be influenced by two concomitant conditions: dehydration and metabolism. The purpose of this study is to test this assumption under varying experimental conditions.

SUBJECTS

Two groups of 16 male naive hooded rats, about 90 days old at the beginning of this experiment, were assigned to two different conditions, i.e., six rats for the water-deprivation groups, the other ten rats for the food-deprivation group.

PROCEDURES

Prior to the experiment, two groups of rats had free access to both water and food in their individual home cages. Then

both groups of rats were deprived. During the deprivation period, the water-deprivation group always had food available and the food-deprivation group always had water available. For both groups, the HR was recorded in their individual home cages at 8 h, 24 h, 48 h, 72 h, and 96 h of deprivation, by a Brush Electronic Company's Type B1-202 recorder via a Type 122 low-level preamplifier and a Model BL-913 DC amplifier. The room temperature ranged from 74 to 78 deg F.

Immediately after the 96 h of deprivation, water was given to the water-deprivation group and food to the food-deprivation group. Thus, both water and food were now always available in their cages. Under these postdeprivation conditions, the HR of both groups was recorded at 10 min, 30 min, 90 min, 8 h, 24 h, 48 h, 72 h, and 96 h, also in their individual home cages.

In order to control confounding factors (e.g., handling, stimulus conditions, etc.), three weeks of adaptation trials (15-min recording of HR daily in the home cage) were given for all rats prior to the beginning of the test trial proper. The harness-electrode was firmly fastened around the rat's shaven chest about 15 min before the test recording proper, except for the first two recordings of the postdeprivation period. For these two recordings, the harness was kept on from the last recording for the deprivation period. A commercial EKG paste was applied to the electrode discs to maximize contact. The test trial proper consisted of a 10-min continuous recording of HR. Since a cardiometer was not available for this experiment, the mean HR was obtained from six randomly selected spots of 30 sec duration each (i.e., a total of 3 min).

RESULTS

The relationship between HR and the hours of deprivation and between HR and the hours of postdeprivation are summarized in Fig. 1. The results for both deprivation groups support our previous findings. The water-deprivation group shows that the HR changes and the hours of deprivation are monotonically related up to 96 h of deprivation. The food-deprivation group did not show a monotonic relation. The HR increased gradually up to about 48 h of deprivation, then decreased as the hours of deprivation increased. An analysis of variance shows that both the HR changes over the deprivation schedules, $F = 3.25$; $df = 5/84$, and the group difference, $F = 6.58$, $df = 1/84$, are significant beyond the .05 level.

Fig. 1. Mean heart rate changes as a function of deprivation and postdeprivation time.

Fig. 2. Mean total body weight changes as a function of deprivation and postdeprivation time.

During the post-deprivation experiment, both the water and the food-deprivation groups show abrupt increments in HR at 10 min postdeprivation. The HRs for both groups gradually decreased down to the levels of ad lib conditions. An analysis of variance shows that the HR changes over the postdeprivation sessions are significant beyond the .01 level, $F = 4.18$, $df = 7/112$, and the group difference is significant beyond the .001 level, $F = 23.11$, $df = 1/112$.

The total body weight changes as a function of the hours of both deprivation and postdeprivation are summarized in Fig. 2. Both groups show very similar trends, except that the body weight loss of the water-deprivation group is slightly more severe than that of the food-deprivation group during the deprivation period. During the postdeprivation period, the water-deprivation group shows a slightly faster body weight gain than that of the food-deprivation group. However, these differences were not statistically significant.

DISCUSSION

The results of the first part of this experiment, i.e., the deprivation experiment, clearly agree with our previous findings (1968) in which the water-deprivation group showed a positive monotonic function, and the food-deprivation group an inverse U-shaped function. The results of the postdeprivation experiment show that both groups show distinct increments in their HR during a 10-min recording period, then the HRs gradually decreased to the ad lib basal levels. From the results of both experiments it appears (1) that HR is influenced by deprivation (either food or water) and (2) that consummatory activities definitely increase HR.

The nature of the inverse U-shaped function obtained from the food-deprivation group requires further consideration. First, consider the total body weight loss of the food-deprivation group. The trend of the weight loss is almost identical with that of the water-deprivation group. And note that water was available to the food-deprivation group during the deprivation experiment.

The total body weight loss of the food-deprivation group during deprivation is influenced not only by a loss of food

stores, but also by a loss of water, or dehydration. During the deprivation of food, electrolytes are first lost continually through the kidneys. As these electrolytes are lost, the kidneys excrete equivalent quantities of water in order to maintain osmotic equilibria in the body. At the same time, an additional quantity of water is lost as the cellular stores of foods are depleted, because the proteins of the cells absorb considerable water. In short, the deprivation of food increases the degree of dehydration in rats. From these physiological facts it was expected that deprivation of food should increase HR. But our data show an inverse U-shaped function suggesting that these food-deprived rats adjusted themselves by reduction in basal metabolism during the deprivation experiment (see also Quimby et al, 1948).

In the case of the water-deprivation group, the degree of dehydration is much greater than that of the food-deprivation group. This is well demonstrated by (1) the total body weight changes during the deprivation experiment, (2) the amount of water intake, and (3) the HR changes during both the deprivation and the postdeprivation experiments. Cessation of water intake increases the degree of dehydration which is, of course, much greater for the water-deprivation group than for the food-deprivation group. Thus, it is expected that HR will increase monotonically only up to a critical period—a critical period evidently occurring sometime after 96 h of water deprivation.

These experimental findings suggest (1) that physiological characteristics measured by the HR change suggest that the deprivation processes of the food-deprived rats are quite different from those of the water-deprived rats; (2) that the rats' HR may be influenced by both dehydration and metabolic changes; (3) that since deprivation itself changes the basal HR level, the HR can be used as a measurement of arousal level as suggested by Malmo (1962); (4) that since consummatory activities definitely increase HR, the HR can be used as a sensitive measurement of conditioning. However, substantial experimental data are required, especially for the reward conditioning, before a suitable general behavioral law can be formulated.

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NOTE

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