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Abstract

It has been demonstrated that food deprivation and access to food are common variables in studies about experimental analysis of feeding behavior and motivational theory. It is unknown if the order of exposure of these variables can modify intake patterns. The present study explores, the effect between food deprivation and access-duration to food was explored. The aim of this study was to explore the effects of food deprivation and food access-duration on food intake in rats. The experimental design included exposure, in ascending and descending order, to both variables. Twelve female rats were assigned to one of each of the four groups: Long Ascending, Long Descending, Short Ascending and Short Descending. It was found that food intake was greater in short groups, independently of the order of exposure. The corporal weight followed the same tendency as the food intake under all conditions. These results are being discussed in terms of their possible implication for the development of excessive or deficit food-intake patterns. To generalize these results it is necessary to have more studies that take account of different combinations of both variables, as well as male rats as subjects.
Key words: deprivation, food access, intake pattern, obesity, rats

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Resumen

Se ha demostrado que las variables privación y acceso al alimento son comunes a los estudios sobre análisis de la conducta alimentaria y teoría de la motivación. Se desconoce si el orden de exposición a estas variables puede modificar el patrón de consumo. En el presente estudio se investigó el efecto de variar la privación de alimento, la duración del acceso al alimento y el orden de exposición a ambas, ascendente o descendente, y se determinó su efecto sobre el consumo de alimento en ratas. Se utilizaron 12 ratas hembras que se asignaron a una de cuatro condiciones que incluyeron duración de la privación, acceso al alimento y orden de exposición. Grupo Largo Ascendente, Grupo Largo Descendente, Grupo Corto Ascendente y Grupo Corto Descendente. Se encontró que el consumo de alimento fue mayor en las condiciones cortas independientemente del orden de exposición. El peso corporal siguió la misma tendencia que el consumo de alimento en todas las condiciones. Se discuten los resultados en términos de sus posibles implicaciones para el desarrollo de patrones de consumo excesivos o deficitarios. Es necesario extender la generalidad de estos hallazgos utilizando más combinaciones de ambas variables y ratas macho como sujetos.
Palabras clave: privación, acceso al alimento, patrón de consumo, obesidad, ratas.

Introduction

In the field of the experimental analysis of behavior, food deprivation is a manipulation variable commonly used by investigators, because it raises the probability of factors in which the investigator is interested. In addition, food deprivation is a characteristic of eating disorders (e.g., anorexia and bulimia). A considerable amount of research, in which the effects of food deprivation on food intake is discussed, is available. For example, it has been shown that a history of food deprivation modulates actual food intake (Franklin, Schiele, Brozek & Keys, 1948; Keys, 1950; Polivy, Zeitlin, Herman & Beal, 1994). In laboratory studies, as deprivation is increased (i.e., 1 to 48 hours without eating) food intake becomes higher (Bolles, 1965; DiBatista, 1987).

The analysis of some variables that modulate food intake in rats has included a great amount of manipulation (cf. Díaz, Franco, Martínez, López-Espinoza & Aguilera, 2009). For example, it has been reported that intake is greater when palatable flavors are included, compared with unpleasant flavors (Holman, 1975; Martínez & López-Espinoza, 2007; Treit, Spetch, & Deutsch, 1982). When the calorific values change, intake of high-calorific content increases when compared with lower-calorific content (Corwin, Wojnicki & Fischer, 1998; Martínez, López-Espinoza & Martínez, 2006). In other procedures, the interaction between the flavor and the calorific content produces differential intake (e.g., Capaldi, 1996; Capaldi, Sheffer & Owens, 1991; Del Prette, Lutz, & Scharrer, 2000). The frequency of food-access is

another variable widely studied and manipulated. It is known that frequent access to food increases intake (Collier, Hirsch & Hamlin, 1972; Díaz, 2008). The food-access duration is another variable that controls food intake. For example, long food-access increases intake, compared with short food-access (Díaz, López-Espinoza, Franco, Martínez, Aguilera & Cárdenas, 2009; Marx, 1952).

Although a great amount of manipulated variables exists that can modify the food intake, previous findings have demonstrated that food access-interval and food access-duration are two common variables in the literature of food intake. It was specifically indicated that comparisons could be drawn with results reported in the theory of motivation and the experimental analysis of behavior (Díaz, 2008; Díaz, López-Espinoza, Franco, Martínez, Aguilera & Cárdenas, 2009).

Exploring the effect of mixing both variables would improve our knowledge about some eating patterns, given that food deprivation and food access time are complementary to each other. For example, being overweight or obese is probably related to the high intake pattern in which food is easily accessed. It could also be a result of continued deprivation periods, followed by a variable duration of food intake and the times these accesses occur. Bellinger and Mendel (1975) compared the amount eaten in a two-hour trial, after variable periods of food deprivation (between 14 to 42 hours), followed by variable food-access periods. They found that rats consumed more food compared with periods of free access to food. They suggested that rats maintained the same pattern of intake regardless of the food-deprivation duration. Even though no change in body weight was reported, it is known that as a variable directly related to food intake (López-Espinoza & Martínez, 2001; Poling, Nickel & Alling, 1990).

In addition to the food access-interval and food access-duration, another variable that is relevant to the control of food intake is the time the food is re-established, given that food intake is different between day and night, generally higher during dark periods than light (Bare, 1959; Bare & Cicala, 1960; Bellinger & Mendel, 1975). In addition, when food deprivation periods to which the rats are exposed are randomly scheduled food intake can be compromised given that the next access to food is less predictable. Therefore, it is necessary to use a design that includes fixed durations for both food deprivation and food access-duration, as well as to control the order of exposure, ascending or descending, to these variables. In this study the periods of food deprivation and access to food were constant, the order of exposure was controlled and the effect on food intake was determined. The aim of this study was to explore the effects of food deprivation and food access-duration on food intake in rats. The experimental plan included an ascending and descending order of exposure to both variables.

Methods

Subjects
Twelve female rats, four months old, and experimentally naïve, served as subjects. Subjects had free access to water during the entire experiment and remained in a 12-hour light-dark cycle. The rats were housed in individual home-cages and were food-deprived using an ascending order, 20-23 or 1-4 hours (Groups Long Ascending and Short Descending, respectively), or using a descending order, 23-20 or 4-1 hours (Groups Long Descending and Short Descending, respectively).

Apparatus
The animals were housed in 12 identical Plexiglas cages (13 x 27 x 38 cm). Each enclosure had a metal cover, with divisions for food and water, and was provided with a layer of sawdust that was removed every three days. Twelve bottles with stainless steel pipettes were used to provide fresh water. During food access-intervals, the animals were fed on Formulab Chow standard for rats.

Procedure
Before the exposition to the periods of food deprivation was programmed, a baseline (BL) was established regarding free access to food and water. This condition was repeated after the last period of deprivation. During all conditions rats were weighed, always at the same time. Every condition changed after 15 days. Deprivation procedure was suspended when body weight decreased by more than 70%, compared with the weight in free feeding. Sessions were conducted on a daily basis over a period of 90 days. All groups were managed at the same time. For all groups the food-access duration was complemented by the food deprivation period over a 24-hour cycle. These were the durations of food deprivation for each group: Long Ascending 20 to 23, Long Descending 23 to 20, Short Descending 1 to 4 and Short Descending 4 to 1. As mentioned, food-access was the complement for a 24-hour cycle.

Results

The amount of food eaten during food access, and body weight, were expressed as a percentage of intake during baseline. The data were handled in this manner because the experiment took more than two months to run and the daily intake of animals varied slightly as they became older and larger. The data were calculated on the last five days of each condition. On each figure, every panel presents the data of the three subjects in each group.

The superior panel of Figure 1 represents the results on the Long Ascending Group. It was observed that food intake progressively decreased as food deprivation increased. Compared with the first condition of free access to food and water (BL),

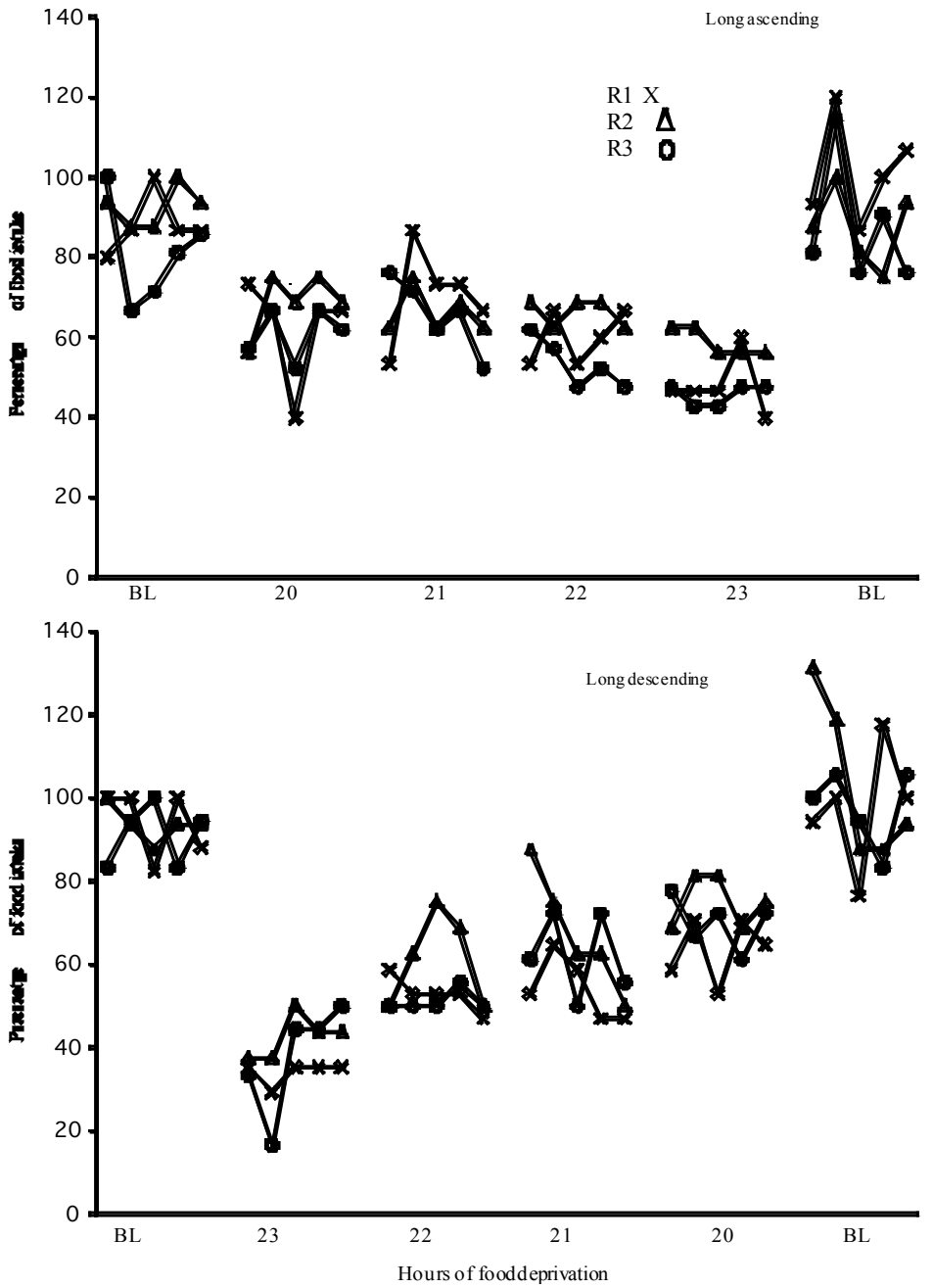

Figure 1. Food intake as a percentage of consumption during free access to food and water (BL).

it was observed that food intake decreased by 50%. Exposure for the second time to free access to food and water, showed that food intake was greater compared with the first baseline; specifically, the intake during the second day was higher than 100% in the first baseline, even though a comparison between intake during free access to food and water did not show significant differences ($t = 1.96$, $p = .97$). The bottom panel of the same figure presents the data for the Long Descending Group. It was found that intake increased progressively during the food deprivation stage. It is worth noting that the change of free access to food, to the condition of food deprivation of 23 hours, decreased food intake, reaching 20%. It should be noted that as the deprivation decreased, the food intake increased, reaching 80%, and during the second baseline, reached above 100%, compared with the findings observed in the first baseline. In this case a significant difference was not observed ($t = 1.93$, $p = .95$).

The superior panel in Figure 2 represents the food intake of the Short Ascending Group. It shows that rats consumed more food while food deprivation increased from one hour to four hours. When the rats had free access to food for the second time, the intake remained above the 100% that was established during the first baseline. In this same figure, the bottom panel shows the data of the Short Descending Group. It was found that food intake increased slightly as the period of deprivation decreased. During the second condition of free access to food and water, subjects consumed the same quantity of food compared with the first time they had free food-access. Data on this figure revealed that any statistical analysis was not necessary.

The body weight of the subjects in the Long Ascending Group are presented in Figure 3. The superior panel shows that the weight decreased as food deprivation increased from 20 to 23 hours. Only in one subject (R1), it was observed that the weight decrease was less than 80%, while the other two maintained around that percentage. When the subjects had free access to food for the second time, it was observed that their weight returned by 100%, compared with the first time they had free access to food and water. In the bottom panel of the same figure it shows the data for the subjects of the Long Descending Group. It was found that in the first baseline of deprivation of 23 hours, their weight decreased from 100% to 80%. During the following conditions, in which the food deprivation decreased from 22 to 20 hours, their weight gradually increased but without reaching 100%. During the second condition of free access to food, the weight was slightly higher than those observed during the first period of free access to food and water.

The body weight of the rats in the Short Ascending Group is shown in Figure 4. The superior panel shows that the weight increased slightly as food deprivation increased from one hour to four hours, by comparison with the 100% observed during the first time of free access to food and water. When the rats had free access again, their weight returned to their normal level, compared with the first time they had free access. In the bottom panel of the same figure, the values of the Short Descending

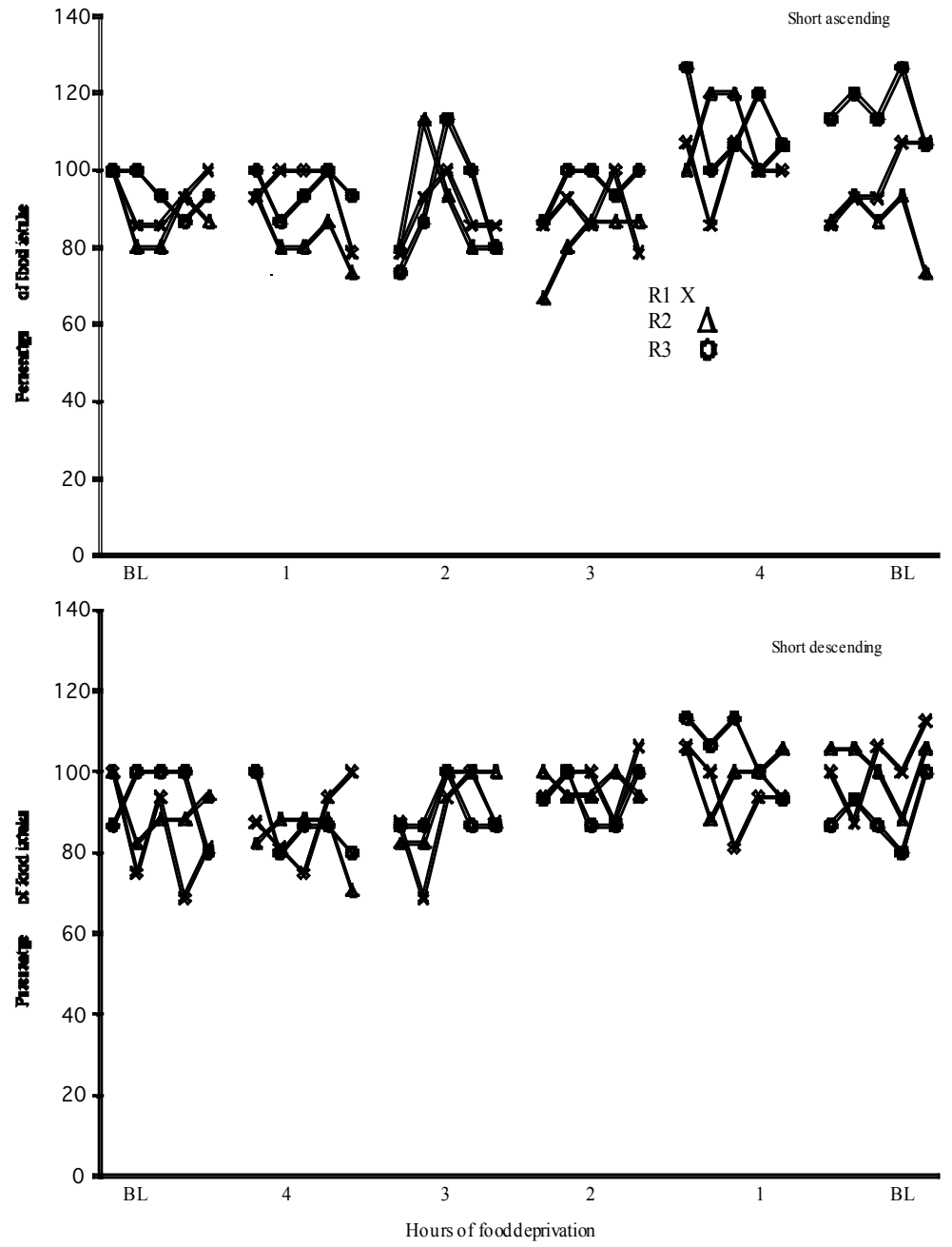

Figure 2. Food intake as a percentage of consumption during free access to food and water (BL).

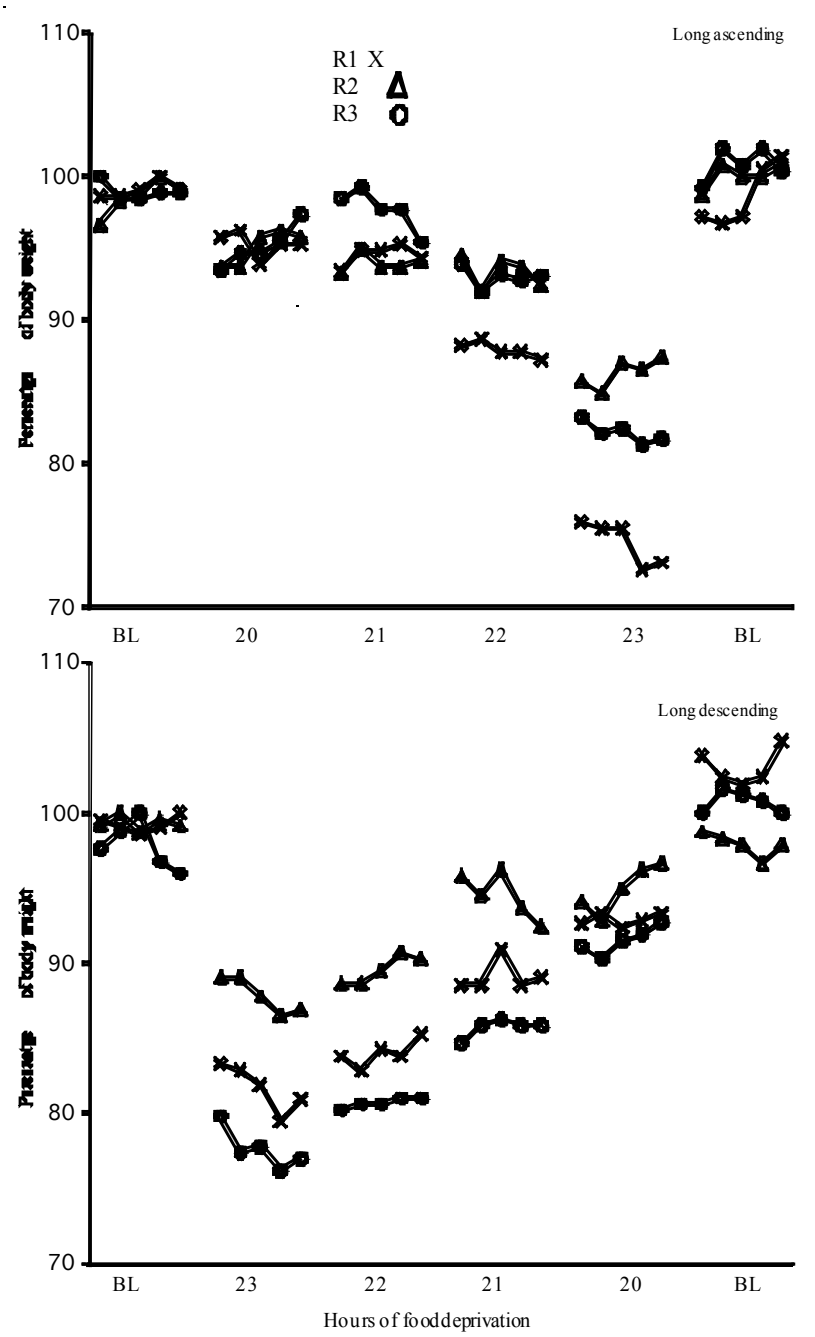

Figure 3. Body weight as a percentage of weight during free access to food and water (BL).

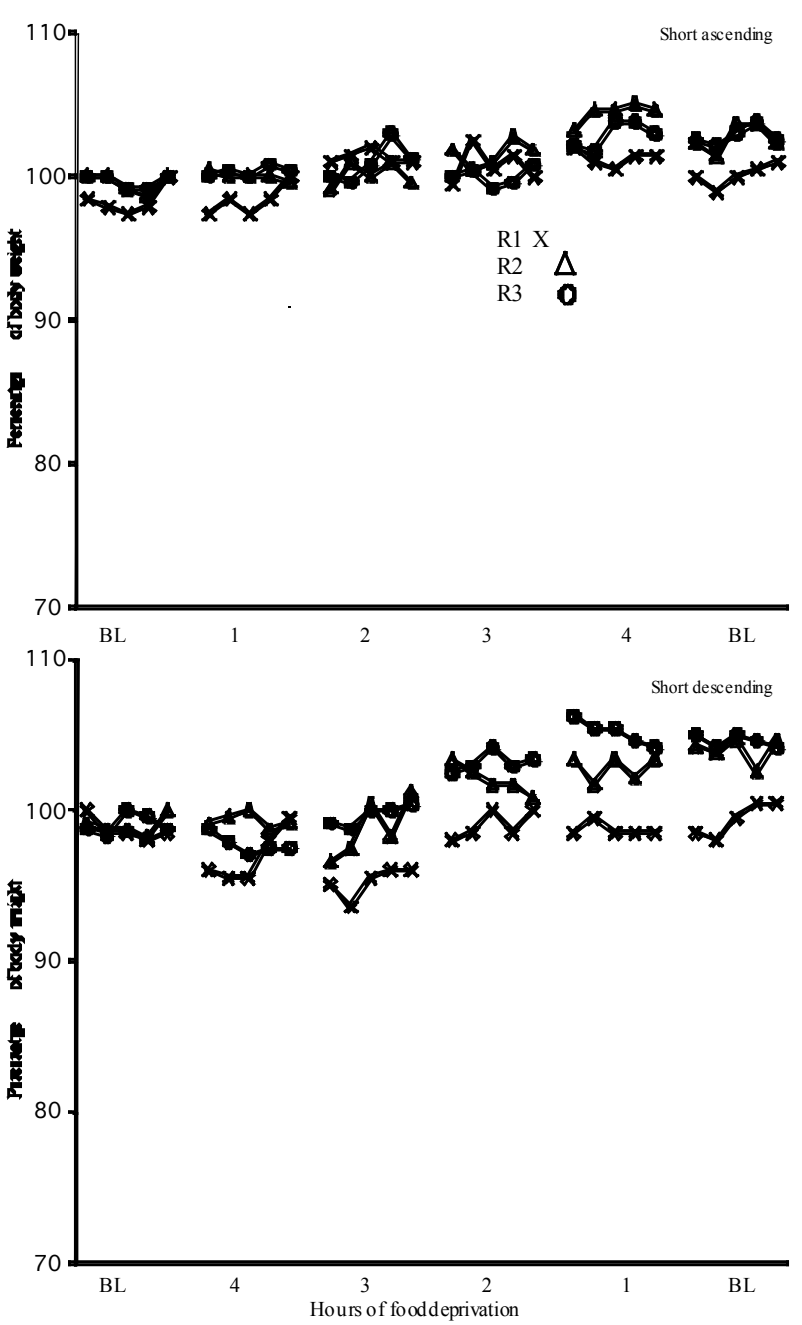

Figure 4. Body weight as a percentage of weight during free access to food and water (BL).

Group are shown. It was observed that body weight increased as food deprivation decreased from four hours to one hour. The weight during the one-hour deprivation, and the second time of free food-access, were practically the same. Between the free access to food and water conditions, it was found that subjects R2 and R3 weighed slightly more during the second time of free access to food and water.

Given the variability of some data, it was necessary to show the consistency of pattern intake. Thus, correlations between food and water intake, and body weight, were calculated. For the Long Ascending Group correlation between food and water intake was positive ($r = .96$, $p < .01$) as well as for food intake and weight ($r = .85$, $p < .05$). Correlation between water intake and weight was positive ($r = .80$, $p = .053$). For the Long Descending Group correlation between food and water intake was positive ($r = .98$, $p < .01$) as well as for food intake and weight ($r = .98$, $p < .01$). Correlation between water intake and weight was positive ($r = .96$, $p < .01$). For the Short Ascending Group correlation between food and water intake was not significant ($r = .28$, $p = .58$) and for food intake and weight was positive ($r = .92$, $p < .01$) and correlation between water intake and weight was not significant ($r = -.03$, $p = .95$). For the Short Descending Group correlation between food and water intake was positive ($r = .09$, $p = .85$) and for food intake and weight was positive and significant ($r = .96$, $p < .01$). Correlation between water intake and weight was not significant ($r = .28$, $p = .58$).

To show the efficiency of the subjects to eat during food access, the rate of intake was calculated. These data are shown in Figure 5 and were calculated considering the last five sessions of each condition. As expected, the rate of food intake was higher in long groups than in short groups, regardless of the order of exposition, ascending or descending. It should be emphasized that the food intake rate increased gradually in the Long Ascending Group. For short groups, food deprivation had the same effect on food intake rate.

Discussion

The aim of this study was to explore the effects of food deprivation and food access-duration on food intake in rats. The experimental design included ascending and descending order of exposure to both variables. For the Long Ascending Group, increased food deprivation yielded systematic reduction in food intake as a consequence of the reduction in the time available for eating during the access-period. When these rats returned to the food and water free-access condition, food intake increased more than 100% registered during the first time of free access to food and water. This finding has been previously reported as binge-eating; because once the deprivation condition is withheld there is no reason to eat more than usual (e.g., López-Espinoza & Martínez, 2001). In fact, binge-eating behavior has been described in humans. Hitherto it was an unsolved problem; thus it is necessary to continue research. The present study does not have the solution either, but shows the effect

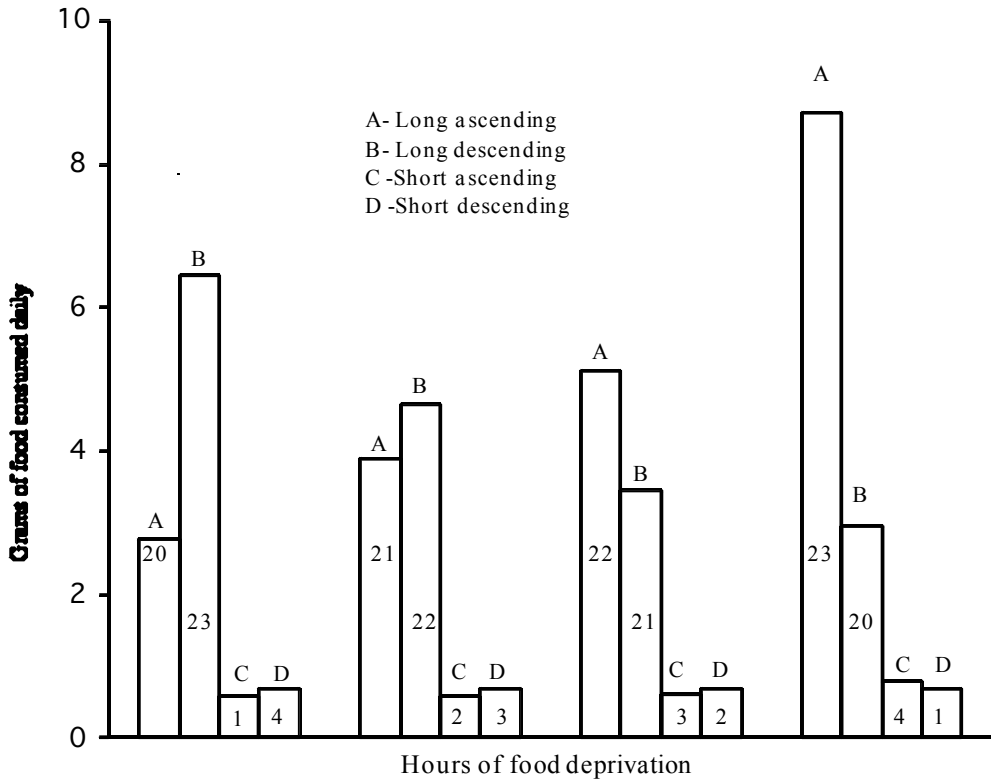

Figure 5. Rate of food intake every 24.hours. Numbers inside bars indicate hours of food deprivation. Capital letters represent every experimental group.

of some parameters such as food deprivation in an ascending order of exposure on food intake. Further studies must be directed to avoid over-intake or to explore its limits (e.g., using more sessions after deprivation). In this sense, this could be a weakness of the present research.

The effect of food deprivation on food intake in the Long Descending Group was the opposite to long ascending. As food deprivation decreased, food intake increased. However, during the second time of free access to food and water an increase in food intake was observed (see Figure 1, bottom panel, subject R1). These findings are contradictory to previous data which suggest that rats can maintain a rhythm of feeding even if they are exposed to periods of deprivation and variable feeding. Bellinger and Mendel (1975) used periods of deprivation that varied from 14 to 42 hours and registered food intake during the first two hours of feeding. For the different groups, food access could be during dark or light periods. They reported that the food intake was greater in darkness than in light period, even after periods

of deprivation between 38 and 42 hours. Even though in the present experiment, regular periods of food deprivation were used and periods of food access were always given during light periods, we did not observe constant patterns of food intake. Rather we found that rats adjusted their food intake to the eating period. In contrast with Bellinger and Mendel's findings, that were registered during two hours of food intake, in this experiment the data was collected during the whole access period, and the subjects were exposed to each deprivation period for at least 15 days. A difference between this experiment and Bellinger and Mendel's study is that during the periods of food deprivation, water was withheld. This means that water intake decreased even though food was ad libitum because of the food deprivation. Complementary to this, the water deprivation decreased the food intake, even though food was available (Fitszimons & Le Magnen, 1969; Roca & Bruner, 2007; Verplanck & Hayes, 1953).

For both short ascending and descending groups, the effect of food deprivation was less noticeable and showed more variability. However, food intake increased slightly regardless of the exposure order, ascending or descending. This finding contradicts the suggestion that pattern of food intake remains constant after food deprivation (e.g., Bare, 1959; Bare & Cicala, 1960; Bellinger & Mendel, 1975) and suggests that increasing the food-access period (from 20 to 23 hours) interacts with other behaviors. This argument is supported by literature that shows the interaction between food intake and other behaviors like grooming, sleeping, resting or exploring, which have been used as indicators of motivational states such as satiety. Based on this finding, subjects of the short groups probably had time to behave in many other ways after eating. Future studies could include a more detailed description using the Behavioral Satiety Sequence analysis (cf. López, Mancilla, & Escartín, 2002 for a review).

Body weight is a dependent variable directly related to food intake. In the present study this variable followed the same pattern as food intake. For the Long Ascending Group, body weight decreased as food deprivation increased (from 20 to 23 hours). For the Long Descending Group, weight increased as food deprivation decreased. Complementary to both short groups, body weight described the typical pattern of growth for rats in a free access to food and water condition (Weihe, 1987). In addition to body weight, correlations between food and water intake, food intake and weight, as well as water intake and body weight, were calculated. Almost all correlations were positive, significant and strong. This finding suggests that despite variability observed in some data, subjects maintained the same food intake pattern throughout the experimental conditions. This result is according to some reports that have shown that rats adjust to environmental changes, such as lean food availability (e.g., Collier et. al., 1972). This finding is very important for the experimental analysis of behavior, because it makes clear the need of more studies that explore the parameters that result in excessive or deficit intake, specifically to determine which parameters that accurately define excessive or deficient food intake. Only then it

will be possible to determine the effect of temporal variables involved in food intake and establish its relationship with patterns of behavior such as anorexia, overweight or obesity (Corwin, 2000; Epstein & Leddy, 2006; Raynor & Epstein, 2003). Regarding the consistency of intake pattern, grams of food consumed were calculated. As predicted, groups with high deprivation ate more food daily than groups with low deprivation. This finding is comparable with the general result showed in the motivational literature. As food deprivation increases, subjects consume more food. Complementary to this, as food deprivation decreases, so does food intake. It is important to state that these findings are valid using 24-hour periods, as were applied in the present study (cf. Bolles, 1967; Coffer & Appley, 1964).

In conclusion, it must be emphasized that it is necessary to extend the generality of the present findings, using new values of both variables, as well as the use of male subjects. New values would help to explore the effects of food deprivation and access to food scheduled during dark periods. Including male subjects will help to control some of the influences due to hormonal changes in female rats.

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