A Theory of Activity-Based Anorexia

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ABSTRACT

The present paper documents the etiological importance of physical activity to self-starvation in animals and suggests similarities between this research area and the literature concerned with some self-starvation in humans. An activity anorexia is proposed that may account for 38% to 75% of anorexia nervosa. An account of excessive locomotor activity is made in terms of schedule-induced behavior. A reciprocally interactive effect of activity and food ingestion is taken to explain self-starvation for animals and activity anorexia in humans. Literature is reviewed which demonstrates that rats and mice self-starve when they are given access to a running wheel and placed on food restriction. In this paradigm, these animals become excessively active and paradoxically reduce food consumption when compared with control subjects. This evidence and related findings are shown to be consistent with a phylogenetically based model of anorexia. Sociocultural factors are hypothesized to set and maintain the conditions that produce activity anorexia in humans.

The hypothesis presented in this paper is that opportunity to engage in locomotor activity interacts with food schedule to produce self-starvation[1] in animals. Additionally, it is argued that this provides a model of an activity-induced type of human anorexia. Such activity-based anorexias may be a subset of the more general diagnostic category, anorexia nervosa.

1. The term self-starvation does not imply a "willingness" by the individual to restrict food intake. Rather it refers to an organismic process involving the reciprocal influence of activity and food consumption induced by phylogenetic and ontogenetic processes. The concept is used to distinguish between starvation as described in this paper and starvation that could be generated by the simple restriction of food.

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Anorexia nervosa is a disorder characterized by a voluntary refusal to eat, extreme loss of weight, and, in some cases, death (Bruch, 1971). It is most prevalent among adolescent females but has been reported in males (Crisp, 1965, 1972; Dally, 1969; Kay & Leight, 1954; Kay & Shapira, 1965; Bruch, 1973; Blitzer, Rollins, & Blackwell, 1961), children, and older adults (Blitzer, Rollins, & Blackwell, 1961; Bruch, 1973). Typical age of onset is 15 to 23 years, with rates of incidence estimated between .24 (Theander, 1970) and 1.6 (Kendall, Hall, Halley, & Babigian, 1973) per 100,000 population. In a recent study of incidence, Kalucy, Crisp, Lacy, and Harding (1977) indicated that the condition is now "common" in greater London, with approximately 1 in every 100 high school-aged women contracting the disorder. These researchers also speculate that the incidence is increasing and the estimated death rate of 5% for hospitalized patients is also taking an upward turn.

The symptoms and psychological correlates are numerous and varied, although some are better documented than others. A prominent and consistent characteristic of anorexia nervosa in women is amenorrhea (Bruch, 1973; Dally, 1969; Theander, 1970), with lesser prevalence of delayed menarche prior to onset (Bliss & Branch, 1960; Kay & Leight, 1954; King, 1963; Morgan & Russell, 1975). The psychological correlates that appear with some frequency involve weight phobia (Crisp, 1965; Bruch, 1965, 1973) and delusional disturbance of body image and body concept (Bruch, 1973; Garner & Garfinkel, 1977). King (1963) reported 21 Australian patients who were categorized into primary and nonprimary groups. Primary anorectics exhibited postpubertal traits of obsessive personality involving egocentricity, sensitivity, shyness, introspection, irritability, and a hostile-dependent attitude toward their mothers. Bruch (1973) indicates four correlates that distinguish "true" anorexia nervosa: (1) concern with thinness and body image; (2) failure to recognize hunger and nutritional needs; (3) deep feelings of inadequacy and inferiority; and (4) obsessive hyperactivity. While most of the psychological symptoms have not been informative with regard to the etiology of this disorder, there is growing clinical evidence that excessive activity may be part of a causal chain that can result in extreme weight loss and death.

PHYSICAL ACTIVITY AND ANOREXIA NERVOSA

Most reports of excessive activity in the clinical literature (i.e., Crisp, 1965, 1972; Slade, 1973; Blitzer et al., 1961; Halmi, 1974; Thoma, 1967) have viewed this behavior as an interesting, but seemingly unimportant, symptom of the anorexia syndrome. For example, Feighner, Robins, Guze, Woodruff, Winokur, and Munoz (1972) have presented diagnostic criteria that includes "periods of overactivity" as one of six possible secondary symptoms. Interestingly, "amenorrhea" is another of these secondary characteristics. In regard to this symptom, Frisch, Wyshak, and Vincent (1980, p. 17) report that for ballet dancers "*who are highly active*. . . there was a high incidence of primary amenorrhea, secondary amenorrhea, irregular cycles and delayed menarch—an incidence correlated with excessive thinness."[2]

There are, however, exceptions to this statement and there is growing evidence that physical activity is important to the understanding of human anorexia. For example, Slade (1973), in an attempt to measure the symptoms of anorexia nervosa, required judges to rate the behavior of anorectics on a 22-item scale. This investigation found that anorectics differed from psychiatric patient controls on resistance to eating, methods of disposing of food, and overactivity. In accord with this latter finding of overactivity, Crisp (1965), in the context of a broader discussion, mentioned activity symptoms of 30 anorectic patients. In his report Crisp states that "the patients were often restless, slept badly, and typically suffered early morning waking and/or waking in the middle of the night." He goes on to point out that phenomena such as overactivity, restlessness, insomnia, and ritualistic behavior develop during the course of self-starvation and recede when the individual has again stabilized eating behavior. In a later paper, Crisp (1972) reports an additional 13 cases of males suffering from anorexia nervosa. Observed behavior included general hyperactivity that was sometimes incorporated into ritualistic behavior and nocturnal restlessness. Also, Crisp, Hsu, Harding, and Hartshorn (1980) performed a retrospective analysis of medical records and found that 38 of 102 anorectic cases showed high levels of exercise during the illness. This report is interesting since medical personnel were not specifically looking for excessive activity. Other clinical investigations have reported incidence of "intense athleticism," up to 75% (King, 1963).

There has been growing recognition that extreme levels of activity may be important to this disorder. In a clinical report, Kron, Katz, Gorzynski, and Weiner (1978) attempted to define the "core pathology" of hospitalized patients with anorexia nervosa. The summary of their findings makes it clear that excessive locomotor activity is critical to the onset and process of (some) anorexias:

> We reviewed the charts of 33 patients hospitalized with this illness during the past 10 years. . . . In 25 of the 33 charts, the presence of hyperactivity during the present illness was recorded; only one patient was specifically noted to show unremarkable physical activity. . . . Among the 13 patients interviewed directly, ten described themselves as continuing to be highly active physically. . . . Physical activity appeared to be more excessive, disorganized, and aimless during the acute phase of anorexia nervosa. . . . These preliminary findings suggest that "hyperactivity" is an early and enduring clinical feature of anorexia nervosa and not merely secondary to either a conscious attempt to lose weight or weight loss per se. (p. 439)

2. While body weight has been implicated in the cessation of menstrual cycles (Frisch & McArthur, 1974), a reviewer of the present manuscript has noted that loss of diapose tissue may precede amenorrhea in athletes and follow it in cases of anorexia. According to the view presented here, body weight loss (which includes loss of diapose tissue) is a predictor of amenorrhea but is not the critical condition. Rather, the excessive physical activity of *both* athletes and anorectics may be the common underlying factor. This view is in fact suggested by Vincent (1981) for ballet dancers and Kron, Katz, Gorzynski, and Weiner (1978) for anorectics. Despite this evidence, few studies of anorexia nervosa have focused on or directly measured physical activity.

While this study presents interesting data concerning activity and anorexia nervosa, it has certain methodological problems. Hyperactivity was only subjectively assessed by coding patients' charts and by collecting self-report measures. Also, experimental bias could have affected these results since the researchers conducted the chart evaluations and interviews. Finally, the absence of a control group makes interpretation of "excessive" activity difficult since there is no baseline for comparison. Given these problems, the Kron et al. (1978) study is only weak evidence for the etiological significance of physical activity in some cases of anorexia nervosa.

Additional suggestive evidence can however be found in the treatment literature. Activity levels of anorectics are often utilized in treatment but again activity is not given etiological importance. Thus, Blinder, Freeman, and Stunkard (1970) used contingent access to physical activity to support weight gain. These researchers report that pedometer measures confirmed hyperactivity in their anorectic patients. During the baseline phase of the study, anorectics walked an average of 6.8 miles per day despite their malnutrition. This compared to women of normal weight, living in the same community, who walked an average of 4.9 miles per day. A major problem with this finding is that the comparison group comes from another paper (Stunkard, 1960). However, it does seem to suggest a high level of activity in women that, because of their poor health, would not be expected. Interestingly, the treatment program appeared to be successful and the authors conclude that "*the reinforcing potency of access to activity may be related to the intensity and high frequency of occurrence of hyperactivity in these patients*" (italics from Blinder et al., 1970, p. 1096).

Interestingly, Mavissakalian (1982) reports the successful treatment of two 17-year-old anorectic females, both of whom were admitted to the hospital following excessive weight loss and other symptoms of anorexia nervosa. A predominant symptom was "compulsive exercising" and this behavior was present for both subjects. An operant behavioral treatment package that required increased food consumption and a one-hour period of rest following each meal was implemented. The rest component was added "to specifically prevent the 'compulsive' exercising which the patient(s) manifested." At discharge, both patients' families were instructed in procedures required to continue treatment. Data show that both subjects became overweight, and an increasing upward trend in weight gain is evident. Mavissakalian interprets these results in terms of weight phobia but observes that it was very difficult to stop compulsive exercising and that after a phenomenal number of sessions the patients, on their own, engaged in sedentary activities. Several other papers have reported successful treatment of anorexia nervosa by making access to physical activity contingent on eating and/or weight gain (cf. Liebman, Minuchin, & Baker, 1974; Garfinkel, Garner, & Moldofsky, 1977). What is not clear is whether it is the contingency procedure or the simple restriction of activity required by the treatment that is responsible for successful outcome.

The possible importance of physical activity to human anorexias is also indicated by psychopharmacological interventions. Chlorpromazine (CPZ) treatment of anorectics has been reported to substantially affect weight gain (Blinder et al., 1970). Crisp (1965) indicates that confining the anorectic to bed and administering CPZ has been an effective treatment. Phenothiazine derivatives have also been used in conjunction with behavioral treatment procedures (Bianco, 1972; Brady & Rieger, 1975). Important for the present concern is the effect of these drugs on general activity. These agents are known to decrease physical activity levels in humans (Byck, 1975, p. 152) and also in animals (Routtenberg & Kuznesof, 1967, p. 418). Further evidence concerning activity and weight control is implied by the pharmacological research on amphetamines. A well-documented "side-effect" of the use of common diet pills is the tendency for individuals to show increased activity levels (Innis & Nickerson, 1975, p. 497). Caffeine also increases activity level and has been associated with anorexia nervosa. Sours (1983) has reported two cases of anorectics who were addicted to this substance. In some instances, these studies indicate that activity changes accompany increases or decreases in food ingestion. It is not clear, however, whether the drugs directly affect eating or only indirectly affect eating through changes in activity levels. Stronger evidence supporting the activity hypothesis may be found in the animal literature concerning weight and restricted food schedules.

FOOD SCHEDULES AND ANIMAL ANOREXIA

While clinical studies of anorexia are suggestive of a relationship between food consumption and activity, such reports can only yield correlational evidence. Additionally, appropriate control groups are difficult to establish. Also, controlled investigations of anorexia with humans have been absent for obvious ethical reasons. Given these restraints on direct analysis of human anorexia, it is important to develop an animal analog of the disorder (see also Mrosovsky & Sherry, 1980).

The relationship of food intake, physical activity, and body weight has, in fact, been investigated at the animal level. An analysis of this literature suggests the presence of a self-starvation model that has similarities to reported cases of human anorexia where excessive activity is present. Routtenberg and Kuznesof (1967) found that rats who were allowed free access to a running wheel and placed on a single 60-minute-per-day food cycle self-starved and died. These animals demonstrated a marked increase in wheel revolutions and this heightened activity was paradoxically accompanied by a dramatic decrease in food ingestion. Control subjects, placed on a similar food cycle but *not* given access to an activity wheel, stabilized body weight and survived. A finding of interest was that injections of CPZ produced a substantial decrease in wheel running and allowed 75% of the experimental animals to survive. It is important to note here that the effects of CPZ are similar to the effects documented in the treatment of human anorexia nervosa.

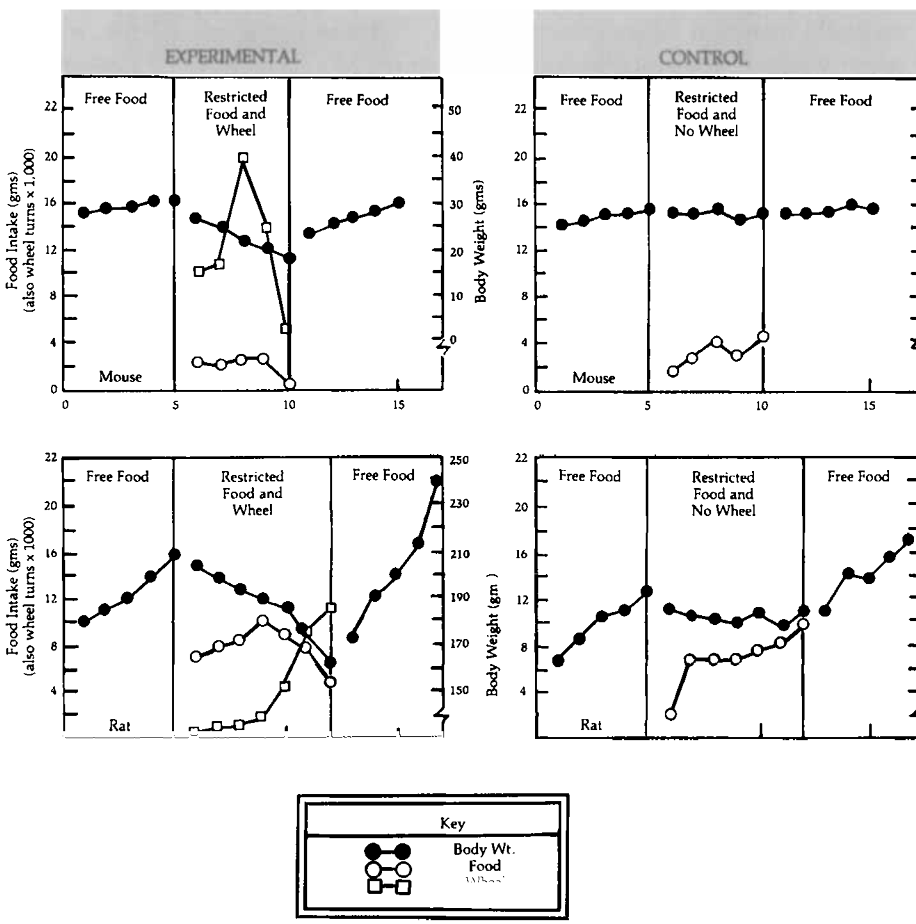
In an attempt to unravel the conditions relating to self-starvation, Routtenberg (1968) isolated some of the variables that might ameliorate the effect. It was found that when rats were given prior experience with a one-hour-per-day food schedule, this procedure generated 75% survival in animals that were later exposed to a running wheel and continued on the food schedule. A second experiment investigated adaptation to the wheel apparatus and indicated that while self-starvation took longer, the percentage of survival (60%) was the same as that of a control group without such adaptation. Routtenberg concluded from these experiments that two factors contributed to the starvation effect. The first factor was novelty stress or adaptation to the running wheel, and the second factor was termed deprivation stress or adaptation to the food cycle. Adaptation to the food cycle was considered to be the more critical factor in this process. In addition, the results indicated that increasing the amount of CPZ over the levels administered in the Routtenberg and Kuznesof (1967) study allowed all experimental subjects to survive. The surviving animals showed a further decrease in wheel turns when compared with the CPZ-treated subjects of the earlier study.

Apparently, Routtenberg did not view locomotor activity as central to self-starvation and did not report levels of wheel running in his novelty stress experiment. On the basis of the present analysis, it would be expected that only animals that increased locomotor activity would show the starvation effect; animals that failed to run (for whatever reason) should survive the experimental treatment. This hypothesis is given indirect support by a control condition in which animals received food restriction but the activity wheels were locked (fixed wheel). Animals in this condition experience the same cage-wheel environment as experimental subjects do but are prevented from excessive activity. Under these conditions all animals survive rather than self-starve, suggesting that activity is an essential aspect of animal self-starvation.

In a brief report that was based on this kind of activity assumption, Epling, Pierce, and Stefan (1981a) extended the analysis of animal anorexia and suggested a link between self-starvation in animals and human anorexia nervosa. In an initial experiment based on the Routtenberg self-starvation paradigm, Epling and his associates extended the effect to another species. In this experiment adolescent male rats (45 days old) and mice (35 days old) were placed in standard laboratory activity wheels with an attached side cage. Experimental subjects were allowed access to a free wheel except when they were provided with food. Access to food was one hour per day for rats and three hours for mice. Control animals were fed on the same schedule but were not allowed to run in an activity wheel. Figure 1 presents data representative of the self-starvation process in these two species. Experimental animals show increasing activity over days and, when compared with controls, demonstrate a drop in food consumption and progressively declining body weight. As noted previously, the activity hypothesis for anorexia implies that wheel running, in these experiments, is a necessary condition for reducing eating in the presence of food. Interestingly, one of the rats did not meet starvation criterion (70% of preexperimental body weight)[3] and did not evidence the increase in running or drop in food ingestion.

Figure 1

Food intake, body weight, and wheel turns for control (no free wheel) and experimental (free wheel available except during feeding) rats and mice. Note that body weight scales are different for rats and mice.



3. The Epling et al. studies employ a weight criterion to define self-starvation. This criterion differs from the Routtenberg definition of less than 1 gram of food consumed per day. While the Routtenberg criterion is more appropriate, current ethical constraints necessitated a weight-based definition since most animals die when eating 1 gram per day.

A second experiment by these researchers (Epling et al., 1981b), with rats as subjects, was designed to investigate the interaction of food presentation and level of activity. Food presentation was food available at all times versus one hour of food available per day. Level of activity was free wheel available versus wheel locked. All subjects were housed in a standard running wheel apparatus with attached side cage. Animals were allowed free access to cage or wheel, with the exception of food-restricted rats, which were prevented from entering the wheel while being fed. Other procedures were similar to those in the Epling et al. (1981a) study reported above. Results were statistically significant and indicated that restricting food and providing an activity source dramatically increased wheel running. When food was restricted and the free wheel available, food intake was severely depressed for experimental subjects when compared with that of appropriate controls. This effect of activity on food intake served to generate a statistically significant downward trend in body weight. The rats in this group were removed from the experiment at 70% of their preexperimental weight. Notably, at this criterion, the animals turned yellow in color and some demonstrated trembling and convulsions.

Overall, the results of these experiments demonstrate that animals placed on a restricted feeding schedule will decrease food consumption if given an opportunity to engage in locomotor activity. Epling et al. (1981a; 1981b) demonstrated that *both* rats and mice will self-starve when exposed to a single meal presentation per day and unrestricted access to physical exercise. These findings replicate those of Routtenberg and Kuznesof (1967) and generalize the effect of self-starvation to mice. While rats and mice are both rodents, these findings are interesting when evaluated in light of correlational data from the human literature. Taken together, the evidence argues for the possibility of an activity anorexia that may occur across several species.

FOOD SCHEDULES AND EXCESSIVE ACTIVITY

A possible hypothesis that could be forwarded to account for the animal self-starvation data (Routtenberg & Kuznesof, 1967; Routtenberg, 1968; Epling et al., 1981a, 1981b) would be that wheel running and the consequent starvation effects are generated by accidental food reinforcement of running behavior, which may compete with food ingestion rather than activity per se. Evidence bearing on a reinforcement hypothesis can be extracted from the Routtenberg and Kuznesof (1967) study. In one of their experiments, they found the starvation effect when the rats were prevented from running for up to two hours before and three hours after the feeding period. This, of course, suggests that reinforcement of running by the food schedule is not responsible for the observed increase in activity. In addition, in all of these experiments subjects were not allowed access to the wheel during the feeding period and this procedure mitigates against a competing response explanation. Further evidence comes from Finger (1951), who demonstrated that rats increased running behavior simply as a function of food deprivation. This paper reports that after 24 and 72 hours without food, 24 hours generated small but reliable increases in running while 72 hours produced an average increase of 94.2%. This evidence clearly argues against a reinforcement or competing response interpretation.

Since high rates of physical activity appear to be central to an understanding of animal anorexia and because, in animal studies, a reinforcement or competing response hypothesis does not seem to account for high-rate activity, it is appropriate at this point to attempt an account of this phenomenon. Researchers have noted excessive physical activity that seems to occur as a side effect of schedules of food reinforcement. This behavior is not required by the programmed contingencies and is therefore called schedule-induced activity (Staddon, 1977; Falk, 1971). Intermittent food schedules may induce a variety of exaggerated behaviors, including excessive water drinking (Falk, 1966), attack (Flory, 1969), wheel running (Levitsky & Collier, 1968), licking at an air stream (Mendelson & Chillag, 1970), and, in humans, smoking (Wallace & Singer, 1976). Wallace, Sanson, and Singer (1977) have shown increased activity in adult humans with eating as the schedule-controlled behavior. Data showed that with free food available, humans operated on a self-imposed schedule. Foster (1978) has pointed to the absence of clinical investigations of schedule-induced or adjunctive behavior with humans and has suggested the following:

> Potential candidates for human adjunctive behavior range from (a) "normal" time-filling or "fidgety" patterns such as playing, idle conversing, finger-tapping, and beard-stroking, through (b) "neurotic" obsessive-compulsive or "nervous-habit" patterns such as nailbiting, snacking, and hand-washing, to (c) "psychotic patterns" such as self-stimulating rituals, manic episodes, and rage out-bursts. Potential candidates for human "inducing" schedules include home, office, classroom, and ward routines, whose time, effort, and consequence properties have long been suspected of side effects by lay and professional people. (p. 545 - 546)

Since these behaviors are exaggerated and persistent and occur at high rates, they appear similar to the pronounced physical activity of many human anorectics. The determinants of these excessive activities have been described by Falk (1977). Two variables consistently appear as critical factors for the production of schedule-induced activity: the length of the interreinforcement interval and the deprivation status of the organism with respect to the scheduled reinforcer. The latter finding may seem paradoxical given the argument that physical activity causes decreased food ingestion. However, as will be outlined at a later point, the relationship of these conditions may be viewed as reciprocal.

Schedule-induced behavior is found to be an increasing monotonic function of food deprivation. Thus, as the period of food withdrawal increases, the probability of schedule-induced activity increases. Interestingly, this is in accord with the Routtenberg (1968) finding that "deprivation stress" was a critical determinant of animal self-starvation. In this experiment, deprivation of food (23-hour food deprivation schedule) with a free wheel available resulted in increasing wheel turns and self-starvation. Routtenberg concluded that deprivation stress was the major determinant of this process.

The relationship of schedule-induced activity to the interreinforcement interval is more complex. Research (Falk, 1966; Flory, 1971) indicates that as the length of the interreinforcement interval increases from small values (approximately 2 seconds) to medium values (between 120 and 180 seconds), there is a direct increase in schedule-induced responses. As the length of the interval is increased beyond these values, the induced behavior begins to decline and reaches a low level at approximately 300 seconds. The interval values explored in the schedule-induced literature are of such short duration that the effects reported are not directly applicable to the determinants of excessive activity in human anorectics. However, the Routtenberg and Kuznesof (1967) study of excessive wheel running and starvation in rats suggests that behavior similar to schedule-induced activity can occur within extremely long food intervals.

Self-starvation studies involve the noncontingent presentation of food after a 23-hour interval. This fixed food schedule is analogous to the constricted fixed time schedules utilized in some schedule-induced experiments (Falk, 1961, 1969). However, the distribution of food in the self-starvation experiments does not correspond to the food distributions investigated in the schedule-induced research. In the self-starvation studies, the animal is given free access to its food all at once after an extended interval. On the other hand, animals exposed to reinforcement schedules of food receive only small amounts of their meal at relatively smaller intervals. A rat may obtain a single food pellet after a brief interval of a few seconds or may obtain its entire food ration for the day at the end of an extended time period of several hours. In both cases, however, it is important to note that excessive activity is generated and maintained. This may reflect the fact that in the self-starvation and schedule-induced experiments, proportionality obtains between the amount of food delivered and the length of the food interval.[4]

A plausible account of the relationship between the schedule-induced literature and self-starvation comes from Collier, Hirsh, and Kanarek (1977). This series of investigations has provided evidence in support of the notion that behavior generated by long food intervals, where an organism may receive an entire meal, is similar to, but not identical with, behavior maintained by typical operant research strategies. The self-starvation research employs long food intervals and analyzes behavior *between* meals, while the schedule-induced experiments use an operant paradigm that employs a short food interval and behavior *within* a single meal is investigated. At the present time, em-

4. This proportionality hypothesis suggests that if meal size is increased with increasing time between meals, locomotor activity will increase or be maintained at high levels. Seemingly contrary to this prediction is evidence from studies of polydipsia that show increased amount of reinforcement is inversely related to level of drinking (e.g., Flory, 1971). These studies did not change interval length proportional to size of reinforcement. Additionally polydipsia is classified as adjunctive behavior, while wheel running is an interim activity (Staddon, 1977). Finally, the proportionality hypothesis pertains to the allocation of meals rather than to bits of a meal or reinforcers.

pirical evidence is not available concerning the allocation of meals (versus reinforcers) and induced behavior. However, the excessive nature of activity in the self-starvation experiments suggests this may be a useful working hypothesis. Interestingly, for the arguments that follow in the final section of this paper, Collier et al. (1977) propose that behavior analyzed between large food presentations, at relatively long intervals, suggests new variables that reflect the structure of the animals' natural environment.

If wheel running of animals in the self-starvation experiments is similar to schedule-induced behavior, then the pattern of wheel-running should be ordered by food presentation. In addition, it might be expected that other adjunctive behaviors would increase within the 23-hour food delivery interval. While the evidence is not conclusive, Woods (1969) reports cumulative records of wheel running by two animals in the self-starvation situation. Running is at high rate and occurs for 6 hours following food presentation, then drops to near zero level for a subsequent 11-hour period, and again increases to a high rate that is maintained over the 6-hour period prior to food delivery. Epling and Pierce (unpublished data) have also noted this pattern in rats exposed to a 90-minute-per-day feeding schedule. Such a distribution of high-rate behavior is highly suggestive of induced activity (Staddon & Simmelhag, 1971). Further evidence from the Woods study indicates excessive water intake or polydipsia for experimental animals. Interestingly, data suggest that polydipsia sharply declines over five days as wheel running dramatically increases for the same period. Since polydipsia is a well-documented side effect of programming schedules of reinforcement (Staddon, 1977), the presence of such adjunctive behavior in the self-starvation experiments lends credibility to the hypothesis that physical activity (i.e., wheel running) is also a form of induced behavior. There are other similarities between the self-starvation and schedule-induced experiments. Most notable is the controlling function of specific stimulus events in the situation (Wayner, 1974). The presence of a licking tube or another animal is critical in specifying and controlling the particular schedule-induced behavior. Thus rats given a drinking tube engage in excessive drinking and those exposed to a conspecific engage in attack rather than some other schedule-related activity. In self-starvation research, the presence of a running wheel, as a specific stimulus event, generates excessive running rather than activities such as grooming or preening. Apparently, these environmental cues are essential to the phenomenon of weight loss and death through high-rate activity.

Overall these findings suggest correspondence between the determinants of schedule-induced behavior and the excessive physical activity found in the research of Routtenberg and Kuznesof (1967), Routtenberg (1968), Woods (1969), and Epling et al. (1981a, 1981b). Paradoxically, there is evidence that excessive activity interferes with subsequent food ingestion.

ACTIVITY AND FOOD INGESTION

The relationship between physical activity and food intake may be reciprocal.

Levitsky (1974) has presented data demonstrating that physical activity reduces food intake. Rats on a free food schedule showed a significant reduction in meals consumed per day when a running wheel was introduced. Notably, food intake was severly depressed for the active animals for the first four to six days following introduction of the wheel. Stevenson, Box, Feleki, and Beaton (1966) also support a reciprocal hypothesis. Their study showed that rats who were forced to run on a treadmill ingested less food than they did when they were not required to run. Additionally, the animals ate less after irregularly presented bouts of forced running or swimming. Several studies have shown that short periods of high-rate exercise decrease food ingestion in male rats (Oscai & Holloszy, 1969; Ahrens, Bishop, and Berdanier, 1972; Crews, Fuge, & Oscai, 1969). Katch, Martin, and Martin (1979) varied the intensity of exercise for male rats while holding total energy output for exercise sessions constant. Results suggested that animals given short-duration exercise of high intensity reduced food intake when compared with subjects exposed to long duration exercise of low intensity. Importantly, both groups decreased food consumption when compared with a control group. In the second experiment by Epling et al. (1981b), outlined in the previous section, control conditions allow the inference that the *interaction* of food schedule and opportunity for activity is the criticial component of self-starvation. Food consumption is first suppressed and then reduced only when a restricted food schedule is in effect and excessive physical activity occurs. With food intake suppressed by high-intensity exercise, body weight declines and this eventually results in the death of the organism (see also, Routtenberg & Kuznesof, 1967).

There is evidence to suggest that this paradoxical effect of excessive activity on food intake can be extended to humans. Edholm, Fletcher, Widdowson, and McCance (1955) report that cadets ingest less food on days of military drilling than they do on days of lower activity. Caloric intake on drilling days was found to be significantly depressed in comparison with other days. Further support comes from Epstein, Masek, and Marshall (1978), who found that obese school children would voluntarily decrease food intake following a prelunch exercise period. Additional support for the notion of reciprocal effects of activity on food ingestion comes from a study by Mayer, Roy, and Mitra (1956). This investigation found that workers who engaged in light to medium-heavy work eat less than do sedentary workers. Johnson, Mastropaolo, and Wharton (1972) reported that 20 college women who engaged in programmed exercise of 30 minutes per day, 5 days a week, decreased caloric intake. Baseline caloric intake was 1,751 calories per day compared with 1,584 calories after ten weeks' exposure to the exercise program. Katch, Michael, and Jones (1969) required 15 previously inactive college women to participate in one hour of tennis or two hours of swimming on a daily basis. Results for both groups showed a moderate decline in caloric consumption. A report by Holloszy, Skinner, Toro, and Cureton (1964) indicates that programmed exercise reduced intake in 15 middle-aged men who were previously sedentary. A decline of approximately 200 calories per day was produced by endurance calisthenics and long-distance running (two to four miles). Finally, Watt, Wiley, and Fletcher (1976) report that 30 middle-aged males with a post-myocardial infarction reduced caloric intake from 2,867 calories per day to 2,088 per day over 12 weeks of programmed exercise. Taken together, these studies suggest that exercise reduces food consumption in humans. This effect appears similar to the effects of activity on food ingestion in animals.

The reduction of food intake when energy expenditure is increasing appears to contradict common sense. The everyday understanding of energy balance suggests a positive relationship between these conditions. In fact, there are studies that report an increase in food intake when activity is also increasing. Mayer, Marshall, Vitale, Christensen, Masayeki, and Stare (1954) found that mature female rats exposed to treadmill exercise showed a positive relationship between activity and intake when duration of activity exceeded two hours. This type of compensation for energy expenditure is also reported in the Mayer et al. (1956) study with humans, which showed that very heavy laborers (i.e., coalmen, carriers, etc.) increased food intake when compared with sedentary workers. Recently, Tokuyama, Saito, and Okuda (1982) have indicated that male and female rats that were allowed access to an activity wheel and maintained on free food show a similar effect. These animals demonstrated increased food intake when compared with sedentary controls. This increase occurred after an initial five- to ten-day decline in consumption. These results suggest that, given enough time, animals and humans can adapt food intake to activity levels *when food is not restricted* (see also Mondon, Dolkas, & Reaven, 1980). This would be the same sort of adjustment expected of most individuals who regularly engage in very active sports, such as long-distance running.

Several of the previously mentioned animal studies (Mayer et al., 1954; Levitsky, 1974; Tokuyama et al., 1982) suggest a nonlinear relationship between food intake and level of activity. Typically, the introduction of an activity wheel for a free-feeding animal results in an initial drop in food consumption. This drop is then followed by an increase that exceeds baseline food intake. Over an extended period of time, activity stabilizes, and this is accompanied by a leveling of food ingestion that still exceeds baseline (see Tokuyama et al., 1982). Thus, the relationship between food and activity is initially negative (up to 14 days), then it becomes positive and, after 20 or more days, stabilizes.

In terms of the activity model of anorexia, the initial negative relationship between food and activity is interesting. This is because activity reduces food intake even under free food conditions. Of course, in activity anorexia, dieting or a restricted food schedule induces even greater levels of activity, which serves to further reduce intake during the "critical period" of negative relationship. The effect of induced activity during this period may be an important contributor to self-starvation. While susceptibility may be enhanced at this time, severe changes in diet and/or physical exertion when the two conditions are positively related may still contribute to the development of activity anorexia.

A THEORY OF ACTIVITY-BASED ANOREXIA

The literature reviewed to this point suggests the presence of an activity anorexia that is a subset of the more general diagnostic category, anorexia nervosa. This evidence also implies an underlying set of conditions that generate the pathology. Thus it is proposed that activity anorexia is based upon the interrelationship of the effects of (1) deprivation and food schedule on activity and (2) activity on food consumption. Briefly stated, it is hypothesized that strenuous locomotor activity works to suppress appetite. This decrease in the value of food reinforcement serves to affect food schedule and/or deprivation, which further augments activity. These factors, excessive physical activity and food restriction, appear to be a sufficient set of conditions for producing activity anorexia. While these conditions combine to produce self-starvation, they may not be the only way activity anorexia is generated. To illustrate, it would be expected that individuals who are very unusually active but who are not on food restriction would run a risk of developing the disorder. In a similar fashion, people who engage in severe dieting or who are on unusual food schedules may also be susceptible.

Humans self-impose food restriction, typically called diets, for a variety of sociocultural reasons. All diets would not be expected to generate excessive activity. The type, severity, and pattern of diet would likely be important variables contributing to high-rate activity. Additionally, sociocultural factors and long-term adjustment to energy expenditure (see Mayer et al., 1954; Mayer et al., 1956; and Tokuyama et al., 1982, in the preceding section of this paper) may operate to maintain food intake in the presence of excessive activity (i.e., football players who must be very active and at the same time maintain weight). In a similar fashion, environmental conditions would operate to affect the rate and type of physical activity. Clearly then, given these restraints, not all people who are very active or who go on diets would be susceptible to activity anorexia. Nonetheless, data (Crisp, Hsu, Harding, & Hartshorn, 1980; King, 1963; Krone et al., 1978) suggest that as many as 38% to 75% of human anorexias may be activity induced.

An increase in the incidence of anorexia nervosa over the past three decades has been well documented (Theander, 1970; Jones, Fox, Babigan, & Hutton, 1980; Duddle, 1973; Garner & Garfinkel, 1980). While more efficient detection of cases may be partially responsible for this rise, most authors believe that the disorder is actually increasing (see Garner, Garfinkel, & Olmsted, 1983). This increase has been accompanied by a corresponding increase in concern for a thin figure (Vincent, 1981). Importantly, recent evidence suggests that current sociocultural standards are more responsible for the "thin-body-image" impact on females than they are on males (Garner et al., 1983). To illustrate, Garner, Garfinkel, Schwartz, and Thompson (1980) report that

Playboy magazine centerfolds and Miss America pageant contestants have become thinner over the past 20 years. In Western culture, an attractive woman is typically young and thin. Vincent (1981, p. 12) has stated that, "By today's standards, Venus was a tad chunky, and a well-intentioned friend might even advise her to enroll at weight watchers." Thus it appears that social and cultural practices, which reinforce women's nutritional behavior, have resulted in increased dieting. This change in dietary patterns, from the point of view of the activity model, could serve to generate a food schedule and level of deprivation sufficient to induce high-rate activity.

The change in Western cultural values regarding thinness has also been accompanied by a corresponding emphasis on physical activity. For example, in Canada, the federal government has supported mass advertising of "Participation," a program designed to encourage sports and physical fitness. Such programs are based upon the health-related benefits of exercise and appear to be widely adopted. The "jogging craze" is one result of this change in cultural expectations. Unlike the cultural standards that support dieting, the value of exercise has not been sex typed. However, according to the activity model of anorexia, people who engage in high-rate physical activity are likely to reduce food consumption. Thus, while many individuals would adjust food intake to level of activity, some would be expected to develop activity anorexia. The development of eating problems among highly active people probably depends upon the rate and type of activity and upon the physical condition of the person. A rapid transition from baseline activity level to a new higher value may make the individual most susceptible to self-starvation (i.e., a fast transition from sedentary to active sports participation or a sudden and intense increase in training schedule for an athlete).

While strenuous physical activity or severe food restriction may have independent effects on the development of anorexia, the animal research on self-starvation suggests that the combined effects of these variables are multiplicative rather than additive. Thus, activity anorexia is most likely to occur in families, social groups, or organizations that encourage *both* high-rate activity and dieting practices. This assertion receives some support from observational studies of athletes and ballet dancers in cases where physical activity is accompanied by limiting food intake. Research on menarche and delayed menarche in athletes (Frisch & Revelle, 1971; Feicht, Johnson, & Martin, 1978) suggests some parallels with diagnosed anorexia. In a recent paper dealing with food aversion and extreme weight loss in athletes, Smith (1980) points to weight problems in both male and female adolescents involved in competitive sports. Most importantly, Smith notes the pronounced similarity between *athletic anorexias* and anorexia nervosa. Typically, these young athletes, in order to reduce body weight to "acceptable" levels, engage in food restriction that becomes excessive over time.

Such food restriction is found in ballet dancers as well and recent evidence also indicates extreme weight loss and amenorrhea in these individuals (see Vincent, 1981). Ballet dancers are involved in a high-activity art form that often requires reduction of body weight through restriction of food consumption as part of the training program. On the basis of the activity model, it would be expected that female dancers are particularly susceptible to self-starvation and extreme loss of weight. Interestingly, a recent study by Frisch, Wyshak, and Vincent (1980) provides tentative evidence for this prediction on the basis of questionnaire reports by 89 female ballet dancers. These researchers were interested in the incidence of delayed menarche and amenorrhea for such females. According to their data, only 33% of the dancers reported regular menstruation. It is important to note that problems of menarche were related to thinness and extremely low weight-to-height scores for a given age. These researchers summarized their results by noting that problems of menarche and low weight were most likely due to the combined effects of hard training and low food intake. The activity model also suggests that within a family setting, a similar emphasis on exercise and dieting may increase the probability of anorexia.

While sociocultural factors appear to be important precipitating and contributing variables for activity anorexia, the underlying condition is most likely phylogenetic. The survival value of locomotor activity in times of food scarcity seems apparent. An increase in activity would serve to take an organism to an area where food is more abundant. The animals of the Epling et al. (1981b) experiments ran as much as 15 or more kilometers per day in their activity wheels. However, as noted with humans and other animals, food consumption declines with increased activity. This anomaly may be understood by considering that travel should not stop when food is *infrequently* contacted since consumption may be negatively balanced against getting to a richer food patch. Also, short-term deprivation should not produce dramatic shifts in activity. This is because occasional limited periods of food depletion would be the norm rather than the exception. However, as deprivation proceeds, it may indicate a serious supply problem and at this time large increases in locomotor activity would have survival value. The point at which deprivation and/or meal frequency generate a large increase in activity should be distributed in a population of animals. A distribution of the characteristic would serve to initiate migrations at different times. This could increase food supplies for animals remaining in the same area and, at the same time, maximize the probability that migrating organisms contact a stable food source.[5]

These observations gain tentative support from the Epling et al. (1981a, 1981b) experiments in which animals are observed to make a large jump in ac-

5. There are animals that do not increase locomotor activity under conditions of food scarcity. Mrosovsky and Sherry (1980) have reported animal anorexias when organisms are molting, incubating eggs, and defending territory. These anorexias typically occur periodically, are of limited duration, and, importantly, are not life threatening. Fasting under these conditions is also related to species survival since eating is incompatible with the particular activity. There are other organisms that react to food shortage by decreasing activity (see Cornish & Mrosovsky, 1965); these animals may hibernate during major seasonal changes when nutritional supplies are affected. Again, this is an adaptive response to an environment where regular fluctuation in food is the norm. Interestingly, hamsters, which hibernate only when they have gathered a supply of food, show an increase in locomotor activity when food is withdrawn. In summary, it is suggested that activity anorexias have survival value for the species and would be most expected to occur in those organisms that do (or have) inhabited ecosystems where consistent supplies of food are typically present.

tivity at several depletion points (typically between 85% and 75% body weight). Additionally, roughly 10% of the subjects in this research do not show a *large* increase in activity and consequently increase food intake and stabilize body weight. Regarding food depletion and its short- and long-term effects, self-starving animals are observed to initially show declining body weight but only slight increases in activity, which are accompanied by small daily gains in food intake. However, following these first few days, the typical animal dramatically increases activity and at the same time *decreases* food consumption. When these animals are then placed on free food and the wheel is removed, they show large increases in food intake and body weight (see Figure 1). Of course this hypothesis would be better tested by allowing the self-starving animal to eat on various food schedules in the presence of a free wheel. Finally, such a phylogenetic process would have more significance for early man or for tribes of hunters and gatherers than it would for people who live in modern technological societies. Nonetheless, given group norms that pressure and reinforce the initiation and continuance of dieting and exercise, individuals may become susceptible to a phylogenetic process that becomes invasive and results in self-starvation. Thus, sociocultural factors are hypothesized to set and maintain the conditions that produce activity anorexia.

Anorexia nervosa, of course, is characterized by many psychological symptoms. While these symptoms may have importance for the etiology, diagnosis, and treatment of many anorexias, they may just as plausibly be by-products of activity-induced self-starvation. Thus, feelings about oneself, perceptions of body state, hostile-dependent attitude to the mother, egocentricity, shyness, sensitivity, introspection, and irritability may also occur as a function of the phylogenetic process outlined here and/or as a function of environmental contingencies (see Skinner, 1969). This suggests that research addressed to anorexia nervosa must attend to phylogenetic and ontogenetic processes in addition to these factors. Such a view also relates human activity anorexias to self-starvation in other species.

ACKNOWLEDGMENTS: Preparation of this manuscript and the research on activity anorexia was supported by University of Alberta research grant #55-32977 and by Alberta Mental Helth research grant #55-66016. Drs. Pierce and Epling share senior responsiblity for this paper. Larry Stefan contributed to the research reported in the manuscript.

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