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EFFECTS OF NUTRITIONAL AND MECHANICAL PROPERTIES OF FOOD ON RUMINATIVE BEHAVIOR

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Previous studies have identified a reliable relation between the quantity of food ingested and ruminating in profoundly retarded individuals and have established some parametric characteristics of this relation. The present study investigated three different properties of food that may influence this relation. Experiment 1 examined the role of stomach distention produced by including in the subject's diet wheat bran in amounts equivalent to and exceeding the calculated amount of crude fiber in the starch-satiation diet reported by Rast, Johnston, Drum, and Conrin (1981) and Rast, Johnston, and Drum (1984). There was a decrease in ruminating, although this decrease was smaller and more gradual than in the starch-satiation condition. Experiment 2 showed that increasing calories without increasing food volume resulted in a gradual and moderate decrease in ruminating. Experiment 3 replicated and extended the first two experiments by varying both caloric intake and stomach distention as well as oropharyngeal and esophageal stimulation in a different sequence of conditions. All variables exerted some control over responding. However, the large and immediate effects of the starch-satiation procedure occurred only when subjects were permitted to consume unlimited quantities.

Key words: appetitive behavior, satiation, self-stimulation, deprivation, rumination, retarded adults

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Rumination is a chronic regurgitation, chewing, and reswallowing of previously ingested food, and it is most often observed in profoundly retarded individuals residing in institutions. Most of the literature that describes research on rumination focuses narrowly on practical methods for controlling the behavior (e.g., Davis & Cuvo, 1980). Although these procedures are often reasonably effective, usually they must be applied on a chronic basis in order to control the behavior to a clinically effective degree (Kohlenberg, 1970).

It may be argued that these therapeutic efforts are constrained by a lack of empirical evidence describing the fundamental relations responsible for the development or maintenance of this behavior. A first step toward the experimental analysis of ruminative behavior demonstrated that the quantity of food ingested during a meal had an inverse relation to the frequency of ruminating following the meal; that is, increases in meal size were related to decreases in ruminating and vice versa (Jackson, Johnston, Ackron, & Crowley, 1975; Rast, Johnston, Drum, & Conrin, 1981). A subsequent study parametrically manipulated the quantity of food ingested and consistently observed the relation in both ascending and descending series between the parametric extremes of normal portions and satiation levels of the standard institutional diet (Rast, Johnston, & Drum, 1984).

The demonstration of this relation suggests a possible role for a number of variables in the etiology or maintenance of ruminating. Increasing the quantity of food ingested at meals involves simultaneous changes in several vari-

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ables that may have effects that can be classified as nutritional, mechanical, and conditioning. For instance, the foods used to supplement the normal diet in the studies of Rast et al. (1981, 1984) were complex starches (e.g., potatoes, rice, grits, cream of wheat, and bread) such that the caloric value of the meals increased with increases in food quantity. The increase in food volume also resulted in more food being chewed and swallowed, thus increasing oral and esophageal stimulation. Finally, the increase in food volume resulted in increasing stomach distention during the immediate post-meal period.

The possibility that these factors influence ruminative behavior is also indirectly suggested by the research literature addressing variables that regulate food intake. This literature indicates that satiety and food intake are controlled by oropharyngeal, gastric, and post-absorptive signals (Jordan, 1969; Thompson, 1980). Although each of these variables has its own independent relation to eating, effective long-term regulation is accomplished only when all three types of variables are present (Jordan, 1969). Single meal satiety (as measured by the cessation of eating) is produced by combined oral and gastric signals. Chewing and swallowing food do not result in satiety, however, if food is shunted prior to entering the duodenum (Young, Gibbs, Antin, Holt, & Smith, 1974). Although oropharyngeal stimulation is not sufficient to produce satiety, it is a necessary component of food intake regulation. For example, despite being given a nutritionally adequate intragastric feeding, humans overeat when allowed oral access to food (Jordan, 1969). Long-term regulation is also dependent on varying plasma concentrations of certain satiety factors, such as the arteriovenous difference in glucose concentration (Code & Schlegel, 1974).

Although it does not necessarily apply to ruminating, this literature does suggest some preliminary directions for an experimental analysis of this response class. The present series of experiments focuses on analyzing certain elements of the food-satiation procedure that bear resemblance to those involved in eating and satiety in order to assess their contribution to the effect of food quantity on ruminating.

Experiment 1 examined a possible physical or mechanical effect—the volume of the stomach contents or stomach distention. This was done by varying the amount of fiber available in the diet, which influences stomach distention due to its water-holding capacity. Dietary fiber is defined as plant material that is resistant to the digestive enzymes of humans and is therefore unabsorbable (Van Soest, 1978). The undigested residue influences the volume and other characteristics of the stool and results in decreased transit time through the intestine (Burkitt, 1976; Kelsay, 1978). Further, increasing the quantity of fiber without increasing calories or food volume results in increased reports of satiety in a single meal (e.g., Grimes & Gordon, 1978). A diet high in fiber-containing foods can result in increased chewing and, thus, in oropharyngeal and esophageal stimulation (Bolton, Heaton, & Burroughs, 1981; Haber, Heaton, Murphy, & Burroughs, 1977). Wheat bran was used because it is a concentrated source that would allow oropharyngeal stimulation and calories to remain near baseline levels. Measured quantities were added to the regular portion baseline diet, allowing the weight, caloric, and oropharyngeal and esophageal parameters to remain essentially constant while increasing the bulk of the bolus in the stomach and upper intestine.

Experiment 2 examined a possible nutritional effect—the caloric density of the meals. Although the satiation diet of Rast et al. (1981, 1984) using increased starches had a higher caloric value than the regular baseline portions, it was not clear whether this contributed to the changes in ruminating that were observed. In order to examine this variable, the weight and volume of the diet were held essentially constant while caloric density was increased to be comparable to the total caloric value of the satiation starch diet.

Experiment 3 replicated and extended Experiments 1 and 2 with a series of manipulations related to the possible roles of both caloric density and stomach bulk. First, caloric intake was again varied, but in the context of large quantities of food rather than using regular baseline meal sizes as in Experiment 1. Then, a sequence of manipulations maintained the calories at near baseline levels while increasing the volume of the stomach contents in a manner that also produced the high levels of oropharyngeal and esophageal stimulation usually accompanying satiation volume meals.

GENERAL METHOD

Subjects

All 4 subjects were profoundly retarded residents at Sunland Center, Gainesville. All were medically screened to determine that structural abnormalities or physiological conditions known to contribute to rumination were not present. Subject RM06 was a 34-year-old male who was nonambulatory, nonverbal, not toilet trained, and who sometimes engaged in self-injurious behavior. He had self-feeding skills and ruminated following all meals. He weighed 84 lbs, although his ideal weight range was 103 to 114 lbs (Metropolitan Life Insurance Company, 1959).

Subject RF03 was a 23-year-old female who was blind, had a moderate hearing impairment, and did not talk (although she followed familiar instructions). She was ambulatory, toilet trained, and fed herself. She ruminated following all meals. Her weight was 98 lbs when this series of studies began (having gained 20 lbs during a previous study), and her ideal weight range was 94 to 101 lbs.

Subject RF04 was a 22-year-old female who was ambulatory, nonverbal (although she followed familiar commands), toilet trained, and performed most basic self-care skills with physical assistance. She, too, ruminated following all meals. Her weight was 84 lbs before the study; her ideal range was 94 to 101 lbs.

Subject RF06 was an 18-year-old female who was blind and deaf, ambulatory, nonverbal, toilet trained, and fed herself. She ruminated following all meals. Her weight was 85 lbs before the study; her ideal range was 82 to 108 lbs.

Setting

Each experiment was conducted in one of two rooms. For Subjects RM06 and RF03 the room measured 4.6 m by 5.5 m and contained two rectangular tables and five chairs. A corner table contained weighing scales and food; the other table was in the center of the room and had two chairs facing each long side. Sessions for Subject RM06 were conducted simultaneously with those of another subject in a different study. These two subjects were seated, well separated, on one side of the table during meals, and each observer sat directly across the table. During post-meal observation periods, RM06 sat approximately 2.5 m away in a rocking chair slightly to the side of the table where the observer stayed. The sessions for RF03 were conducted with only her observer present, and during the post-meal period she continued to sit at the feeding table.

For Subjects RF04 and RF06 the room measured 4.9 m by 7.8 m and was partitioned into four three-sided enclosures that measured 2.2 m by 2.5 m. A small square table was in the corner of each enclosure with a chair on two adjacent sides. The subjects sat in separate enclosures at the table while eating and remained there during the observation period. The observer sat in the other chair approximately 1.0 m away from the subject.

Measurement

During the meal the observer monitored the subject's eating. He or she kept the subject's tray full until all scheduled food was consumed or until the criterion for meal completion was met. This consisted of the subject emitting three of any of the following responses without intervening eating: setting the utensil down, spitting out food, or getting up from the table. Following the meal the observer counted each ruminating response during the post-meal observation period (these subjects ruminated only after meals). The duration of the post-meal observation period was 60 min for Subjects RM06 and RF03 and 30 min for RF04 and RF06. The topography of the ruminating responses was quite distinctive and stable for each subject, and the topography was perfectly correlated with the functional response-class

Table 1
Calibration and Interobserver Agreement Data

Procedure	*Subjects*	*# Sessions*	*% Correspondence Frequency*
Calibration	RM06	9	93-100
	RF03	16	95-100
	RF04	14	91-100
	RF06	12	90-100
Interobserver	RM06	13	95-100
	RF03	19	96-100
	RF04	18	93-100
	RF06	14	92-100

definition requiring food to come into the mouth from and return to the esophagus and stomach. Response frequency was calculated for each session. Calibration procedures were followed in training and assessing all observers (Johnston & Pennypacker, 1980) and were the same as those reported in Rast et al. (1981, 1984). Table 1 shows these data.

Experimental Procedures

Experimental sessions were conducted at two meals per day for each subject. Breakfast was served at 7:00 a.m., lunch at noon, and supper at 5:00 p.m. Experimental sessions for RM06 and RF03 were conducted at breakfast and lunch, for RF04 at lunch and supper, and for RF06 at breakfast and supper. At the other meals the subjects received the same quantity and types of food as at experimental meals; however, they ate these meals with the other residents in their cottages and no observations were made. All dietary manipulations were made with the guidance and assistance of professional dietitians on the staff at Sunland Center. All meals were prepared by the institutional kitchen staff, measured by dietary staff, and weighed by the observer. At least once in each phase the foods were weighed a second time by an additional observer (for 79 such checks no discrepancies exceeded 1 oz).

EXPERIMENT 1

Method

Subjects RM06 and RF03 served in this experiment. In the baseline phase each subject received increased portions of the standard institutional diet. Breakfasts typically consisted of fruit juice, eggs, white bread, hot cereal, and milk. Lunches and suppers included milk or juice, diced meat, green vegetable, starch, white bread, and fruit.

This standard daily diet contained approximately 4.8 g of crude fiber; in contrast, the satiation diet of Rast et al. (1981, 1984) contained approximately 10.1 g. The experimental phases added wheat bran to all three daily meals. For RM06, 1 tablespoon (tbs) of bran was added to each meal during the first experimental phase (3 tbs per day), and 1.5 tbs was added during the second phase (4.5 tbs per day). For RF03, 2 tbs of bran were added to each meal during the first experimental phase and 3 tbs per meal during the second (totaling 6 and 9 tbs per day, respectively).

Each tablespoon of bran is equivalent to 0.9 g of crude fiber (Van Soest, 1978). Thus, the resulting amounts of crude fiber added to the 4.8-g baseline diet were 2.7 and 4.0 g per day for RM06 and 5.4 and 8.1 g per day for RF03. Because it is important to consume supplementary liquids when on this type of diet, an additional total of 64 oz of noncaloric liquids were administered daily in all phases of this experiment. This liquid was distributed throughout the day in small quantities, but not during the hour before or after meals. Wheat bran increases stomach distention by absorbing liquid in the stomach but produces only negligible increases in caloric intake and stimulation. There are 10 calories per tbs of bran, so only 30 to 90 calories per day were added by the bran (in contrast to the 1580 calories per day added in Experiment 2, in which calories were explicitly varied). The bran was mixed in the food and may have produced some additional chewing, but no more than a small fraction of the total amount of chewing necessary to consume a meal.

Results and Discussion

In general, the data describe an inverse relation between dietary fiber and ruminating. Ruminating decreased very slightly when wheat bran was added to the baseline diet, decreased slightly more when the amount of added bran was increased further, and increased to base-

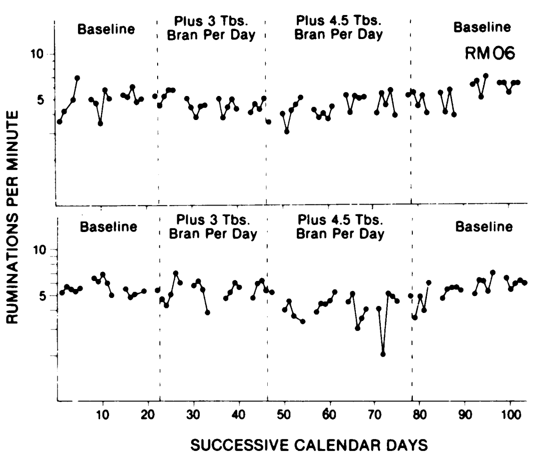

Fig. 1. Frequency of ruminating (logarithmic scale) after breakfast and lunch meals for RM06 under baseline and added-fiber conditions.

line or near baseline levels when the additional bran was terminated in the last condition. These changes in responding were small and gradual, however, compared to those reproted by Rast et al. (1981, 1984).

Figure 1 shows the frequency of responding for Subject RM06 displayed separately for breakfast (upper graph) and lunch (lower graph) meals on a semi-logarithmic graph. Baseline responding was relatively stable, with medians for the phase of 5.2 after breakfast and 5.5 after lunch. The 3 tbs per day added-bran condition was accompanied by a decrease after breakfast to a median of 4.3, while post-lunch responding showed no appreciable change. In the second added-bran phase, the changes in responding were equally slight: medians of 4.1 and 4.4 for breakfast and lunch, respectively. However, responding did gradually increase under the final no-added-bran condition to the levels observed in the original baseline.

Figure 2 shows the responding of RF03 under a similar sequence of conditions, except that she received even greater amounts of bran than did RM06. After-breakfast response frequencies did not decrease noticeably in the first added-bran condition, but when the amount of added bran was increased to 9 tbs per day in the next phase, responding dropped from the previous median of 1.3 responses per minute to 0.71 responses per minute. (The latter value is based on the entire 45 sessions of that phase, 21 of which are omitted, for brevity, from the figure.) Rates increased rather quickly when bran was no longer added to the regular diet in the last phase. Responding was somewhat more variable after lunches, showing an increasing trend in baseline, a decrease under each of the added-bran conditions, and an increase in the last baseline phase.

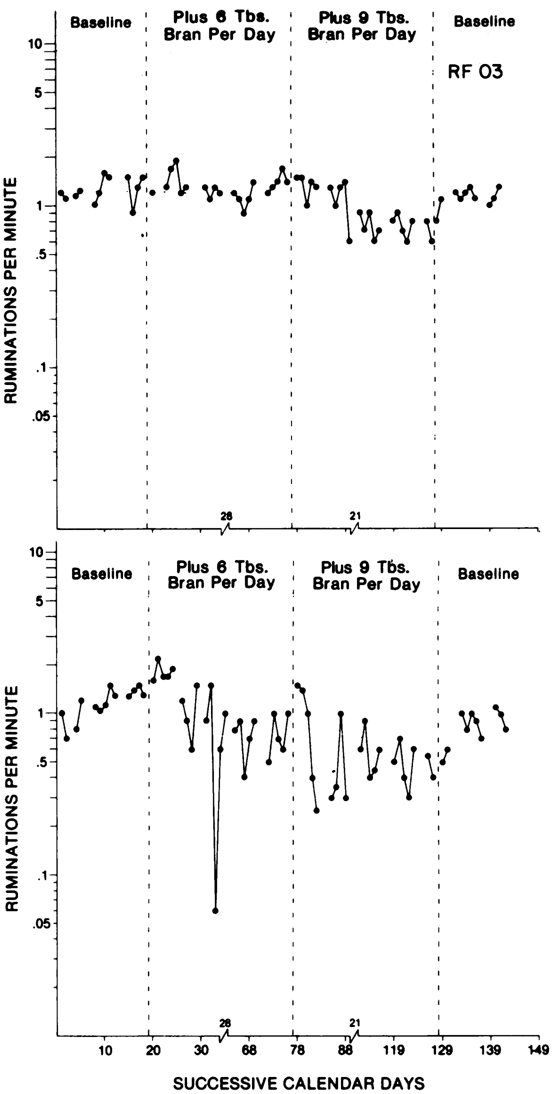

Fig. 2. Frequency of ruminating (logarithmic scale) after breakfast and lunch meals for RF03 under baseline and added-fiber conditions.

Across the 2 subjects the decreases in ruminating under added-bran conditions were positively correlated with the amount of bran added: 3 tbs per day was accompanied by almost no change and 9 tbs per day was correlated with the largest decrease. However, even this decrease was only moderate compared to the immediate and large reductions in ruminating reported by Rast et al. (1981, 1984); in fact, both RM06 and RF03 also served in the parametric study of food quantity (Rast et al., 1984).

Although the exact relation between bulk of food in the stomach (or stomach distention) in the added-bran conditions and that of the satiation diet conditions of Rast et al. (1981, 1984) cannot be known with certainty, the parametric values of this experiment covered a reasonable range. While the satiation meals were calculated to contain 10.1 g of crude fiber, the bran conditions added 2.7 to 8.1 g to the calculated 4.8-g content of the standard diet to total 7.5 to 12.8 g per day. Thus, these manipulations did vary the stomach and upper intestine bulk or distention over a wide range while keeping oropharyngeal stimulation and caloric intake at near baseline levels, but the resulting effects were relatively small.

EXPERIMENT 2

METHOD

Subject RF03 also served for this experiment, which was conducted immediately following Experiment 1. All meals in the initial and final baseline conditions shared the same characteristics as the baseline meals in Experiment 1, and their combined daily caloric value was approximately 3400 calories. In the intervening experimental condition, the daily caloric content of the diet was increased to approximately 4980 calories, the same level as that of the starch-satiation diet used by Rast et al. (1981, 1984). This increase in calories was accomplished by using whole, rather than skim, milk; adding extra butter, oil, and jelly; using starchy vegetables; and decreasing high-bulk, low-calorie foods. These particular changes were made in order to maintain the volume, weight, and chewing requirements of the diet essentially unchanged from those of the baseline diet, while matching the caloric value of the starch-satiation diet. Although no direct measures were made of stomach bulk or chewing and swallowing responses in these conditions, the volume and weight of the high-calorie diet were matched to the baseline diet, and variations in stomach bulk and oropharyngeal and esophageal stimulation were minor compared to the values of these parameters imposed by the starch-satiation diet of Rast et al. (1981, 1984) and Experiment 3.

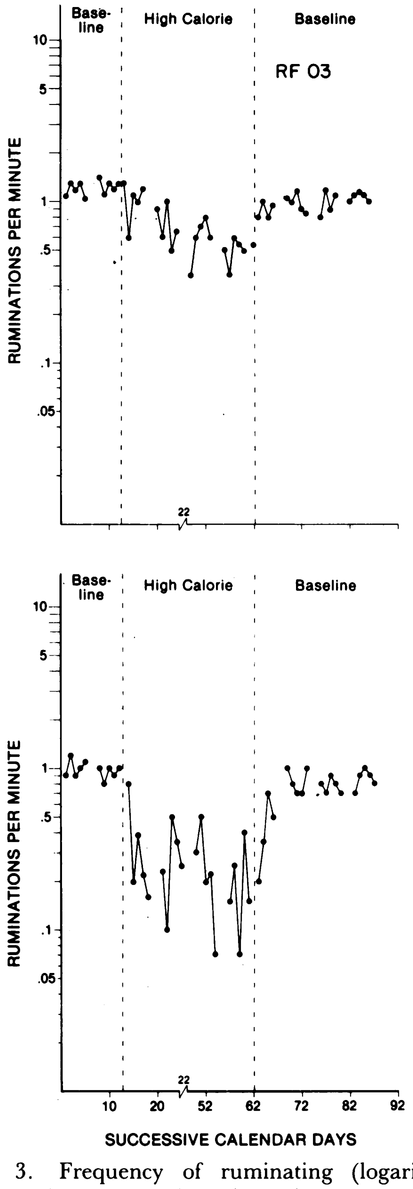

Fig. 3. Frequency of ruminating (logarithmic scale) after breakfast and lunch meals for RF03 under baseline and high-calorie conditions.

Results and Discussion

Figure 3 shows the frequency of responding for RF03 on successive calendar days across baseline, high-calorie, and baseline conditions (except for the omission, for brevity, of 22 days from the middle of the experimental phase). Post-meal responding was quite stable under baseline conditions. When the high-calorie diet was begun at breakfast, responding showed an immediate downward trend, stabilizing at about 0.5 responses per minute, compared to about 1.3 responses per minute under baseline. The decrease in responding under the lunch high-calorie condition was more immediate, large, and variable; baseline frequencies were tightly clustered around 1.0 per minute, but high-calorie responding ranged from one every 2 min to as few as one in 30 min in the high-calorie condition. The return to the final baseline phase was accompanied by an immediate transition after breakfast and a rapid transition after lunch to stable responding slightly lower than that under the original baseline.

The observation that the change in responding under the high-calorie condition was more immediate and large after lunches than after breakfasts suggests an interaction between these two adjacent meals similar to that reported by Rast et al. (1984). In this earlier parametric manipulation of food quantity, the frequency of responding following lunches was clearly and substantially influenced by the quantity of food consumed at the prior breakfast meals. The identification of the critical variable(s) responsible for the general relation may aid in understanding the reasons for this temporal feature.

In spite of the moderate to fairly large decreases in responding under the high-calorie condition, the reduction in ruminating was not complete, as it was for RF03 under the satiation diet (see Rast et al., 1984). The data from this one subject suggest that the caloric value of the satiation diet may be one of its more potent component variables but that other variables also contribute to the effect. Whatever the critical variables in the satiation diet, however, these data suggest that the caloric density (calories divided by weight) of the food consumed does influence ruminating.

EXPERIMENT 3

Method

RF04 and RF06 served as subjects in Experiment 3, which was designed to replicate and further pursue the variables examined in Experiments 1 and 2. As such, the different phases of this experiment involved changes in different variables, which must be interpreted separately. Experimental meals were lunch and supper for RF04, whose breakfast meal quantities were slightly larger than those of the standard diet and remained unchanged across experimental conditions.

Manipulations for both subjects began with a replication of the basic satiation-diet procedure in which the extra food was in the form of starches. An initial baseline condition was followed by a starch-satiation condition in which the median quantity of food consumed was 44 oz by RF04 and 39 oz by RF06. Following this phase, baseline meal sizes were reinstated.

To further examine the role of caloric density, the next phase increased the volume of the food consumed at experimental meals so that it matched the level of the satiation meals while holding its caloric value at baseline levels. This was accomplished by adding volume to the baseline diet in the form of high-bulk, low-calorie vegetables and by decreasing fats and oils. This allowed a comparison between this phase and the satiation phase in which the volume was the same but caloric intake was much higher. This comparison thus permitted an evaluation of the influence of caloric intake in a manner opposite to that permitted in Experiment 2, in which caloric levels increased to satiation levels while other variables remained at baseline diet levels. In both cases caloric levels were varied between the parametric extremes that were permissible while other variables remained relatively unchanged. (In Experiment 3 there was a slight difference in the weights of the diets; there was no measure of any changes in the oral stimulation engendered by the matched-volume condition, but it could not have been large.)

The next phase adjusted for the fact that most vegetables weigh less than starches (for example, 10.1 cups of the vegetables used in the matched-volume condition and 5.4 cups of starches each weighed about 45 oz). The quantity of food consumed in this phase was increased so that its weight matched the weight of the food consumed under the satiation condition. This required an additional 10 oz per meal for RF04 and 8 oz per meal for RF06. At this quantity, daily caloric intake unavoidably increased by about 50 calories.

In the final phase both subjects were allowed to eat all of the high-bulk, low-calorie vegetable diet they could. RF04 consumed a median of 62 oz per meal, and RF06's median quantity was 50 oz per meal. Although the daily caloric intake again increased slightly, it still was only 150 to 250 calories higher than 3400-calorie baseline level (far below the 4980 daily caloric level of the satiation-starch condition).

Results and Discussion

The sequence of baseline, satiation, baseline conditions was accompanied by the same changes in responding reported by Rast et al. (1981, 1984). Figures 4 and 5 show data collected following each of the two experimental meals for RF04 and RF06, respectively. High rates of responding under the initial baseline condition were followed by a rapid transition to very low rates (often no ruminating at all), and the return to the basline diet was followed by an immediate change in responding to original baseline levels. These data fully reproduced the relations already reported by Rast et al. (1981, 1984) and established the satiation-level food quantities for these 2 subjects (this had already been done for RM06 and RF03 by Rast et al., 1984).

The comparison of responding under the satiation condition and the matched-volume baseline calorie phase showed the same effects in both subjects: Responding was considerably higher under the latter condition. In other words, the effect of reducing calories while volume was kept at satiation levels was a large increase in responding, whereas in Experiment 2, in which calories were increased while volume was kept low, there was a moderate decrease in responding. The combined data from all 3 subjects exposed to calorie manipulations suggest a significant role for the caloric value of the diet.

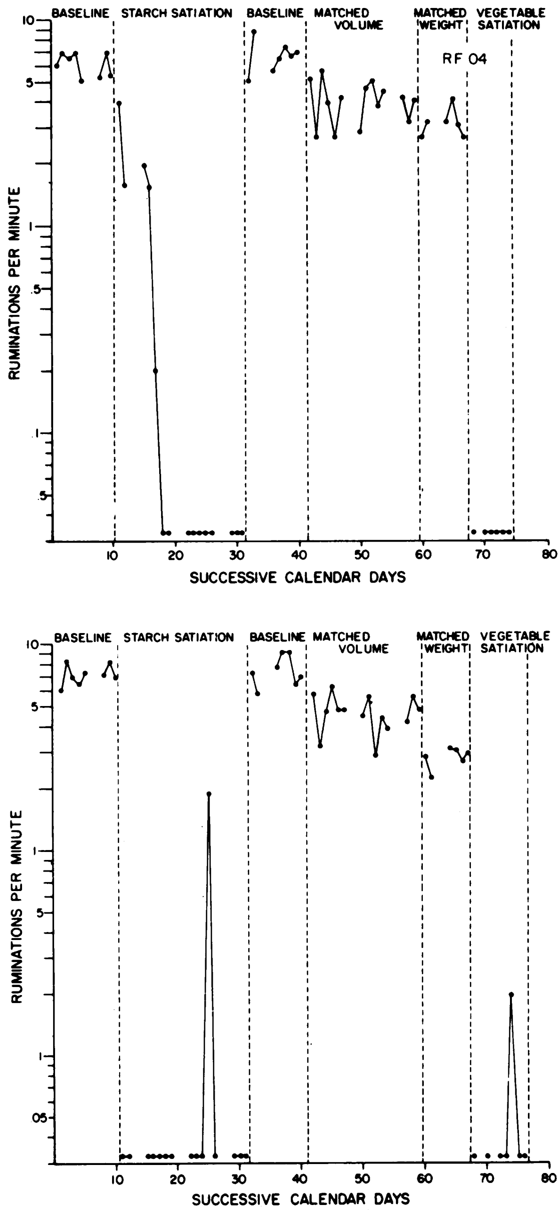

Fig. 4. Frequency of ruminating (logarithmic scale) after successive sessions for RF04 under baseline satiation, matched-volume, matched-weight, and satiation vegetable-diet conditions.

When the quantity of food consumed was further increased so that its weight matched the weight of the satiation meals, the data

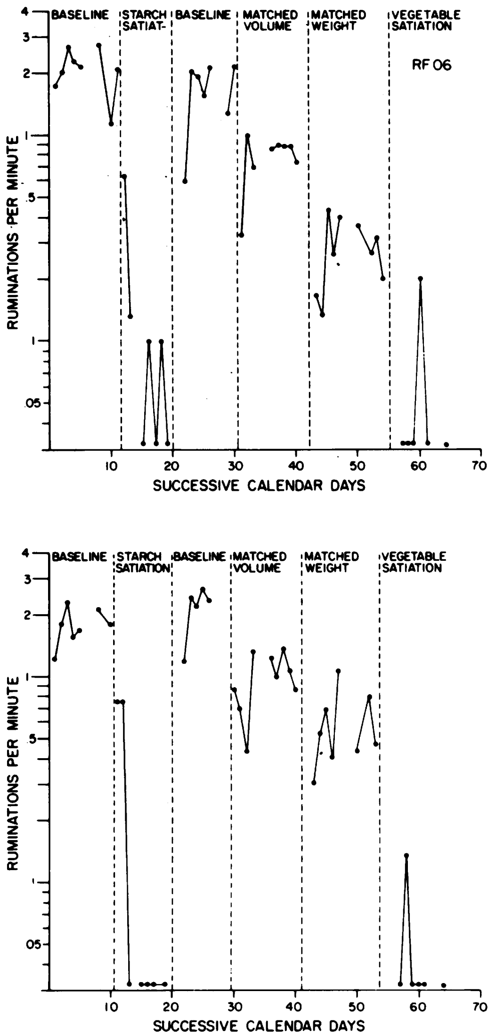

Fig. 5. Frequency of ruminating (logarithmic scale) after successive sessions for RF06 under baseline satiation, matched-volume, matched-weight, and satiation vegetable-diet conditions.

showed a relatively slight, yet clear, decrease in responding across all four meals with both subjects. Furthermore, as with the matched-volume condition, the change in responding at the beginning of the phase was immediate. Only when the quantity of food consumed was determined by the subjects themselves, in the final vegetable-satiation phase, did responding almost cease entirely as observed in the original satiation phase. However, both subjects were consuming considerably larger quantities of food in the latter satiation phase (18 oz per meal for RF04 and 11 oz per meal for RF06).

Unlike the matched-volume phase, these last two conditions presumably increased both stomach volume and oropharyngeal stimulation above starch-satiation levels, and the relative contributions of these two variables cannot be differentiated with these data. However, increases in these two variables were accompanied by only very small changes in caloric intake compared to the starch-satiation diet, thereby suggesting that stomach bulk or oropharyngeal stimulation may play a significant role in the relation between food quantity and ruminating.

GENERAL DISCUSSION

The data from these three experiments contribute to an improved understanding of the relation reported by Rast et al. (1981, 1984) between the quantity of food ingested and ruminating. In particular, the nutritional variable of caloric value was shown to have a moderately large inverse relation to ruminating. Responding was clearly and substantially reduced when baseline meals were given the caloric value of starch-satiation meals; however, responding did not decrease as immediately or as greatly as observed in the earlier studies. Nonetheless, responding returned quickly to baseline levels when the extra calories were terminated.

These effects with a single subject were reproduced in a systematic replication with two other subjects in Experiment 3. A comparison of responding under a satiation condition and one that was matched in volume but that removed the extra calories again showed the moderately large effects of calories on ruminating.

Finally, the matched-volume, matched-weight, and vegetable-satiation phases of Experiment 3 also provided some evidence to support the role played by calories in controlling rumination. That matching volume while keeping caloric intake at near baseline levels was not followed by extremely low levels of responding characteristic of the starch-satiation diet suggests that caloric level might have been a factor. In other words, if caloric intake were not a contributing variable, then the matched-volume condition should have maintained the same low levels of ruminating of the starch-satiation condition. The same argument applies to the matched-weight condition, although inferences here about caloric intake must be tempered with the possibility of higher levels of stomach bulk and oral stimulation than under starch satiation. Similarly, the fact that when the subjects were permitted to free feed with the high-bulk, low-caloric diet they consumed 22% to 29% more food by weight than under the original starch-satiation diet also suggests the possible influence of caloric level because it constituted the major difference between the two satiation conditions (although the influence of undetermined, but possibly slightly higher, levels of stomach bulk and oral stimulation must be considered as well).

It is not clear how caloric intake may produce its effects on ruminating. The characteristic effect with the starch-satiation procedure includes a very rapid transition in response rates, whether the diet is being initiated or terminated. A large change in responding usually occurs immediately after the first meal on or off the diet. However, the digestive processes are only beginning in the first half hour after a meal, although this period is extended by about 30 min if timing begins at the beginning of a meal. The data from Experiment 2 that show the effects of caloric intake alone suggest that its influence is indeed gradual rather than immediate, thus further suggesting that the satiation effect results from the combined effects of multiple variables.

The other variable directly assessed in these experiments was stomach bulk or distention, the effects of which would presumably be mechanical in nature. The results of Experiment 1 showed a much more modest role for this variable than for caloric density. Even with the largest amounts of wheat bran added to the regular baseline diet, the decreases in responding were fairly small. However, this conclusion must be tempered with some uncertainty about how well the effect of the starch-satiation diet on stomach volume was replicated by adding bran to the regular baseline diet.

The data from Experiment 3 avoided this concern by successively matching the starch-satiation diet in volume, weight, and under free-feeding conditions with a diet that was high in bulk, but which kept calories at near baseline levels. However, the matched-volume condition was accompanied by only a relatively moderate effect. Even further increases in quantity in order to match the weight of the starch-satiation diet corresponded only to another relatively modest decrease in response frequency.

These data would seem to confirm that stomach volume may contribute to the control of this response class; however, their interpretation is confounded by possible oropharyngeal stimulation, the variable that Experiment 1 was designed to avoid. The consumption of this high-bulk, low-calorie diet under the matched-volume and matched-weight conditions meant that the amount of chewing and swallowing increased with increases in food quantity, and oropharyngeal and esophageal stimulation is itself a variable of possible potency. The fact that responding ceased almost entirely only when the subjects were permitted to consume all that they could using the meal completion criteria, whatever the nature of the food, suggests the influence of this variable.

If oropharyngeal stimulation were a contributing variable, it would most likely play that role as a reinforcer. Not only has this been suggested by Ball, Hendricksen, and Clayton (1974), it is a reasonable hypothesis based on informal observation and is probably a working assumption for many therapists. Nevertheless, the function of oropharyngeal stimulation in ruminating has never been experimentally addressed.

"Satiation" refers to a temporary decrement in the reinforcing efficacy of a class of stimuli following a period of frequent presentation. In this case the stimuli whose reinforcing effectiveness may temporarily decline after a period of frequent presentation might be oropharyngeal and esophageal. After normal-size meals these stimuli can be repeatedly produced so long as there is sufficient food in the stomach (given that the individual has already acquired this skill). When the individual eats until he or she will no longer consume the food that is available, the increased amount of chewing and swallowing required to ingest these very large quantities may temporarily reduce the reinforcing efficacy of the stimuli associated with these responses. As a result, in spite of the greater amount of food in the stomach that is available for rumination for a longer period of time, the individual may emit the response much less often, if at all, in the post-meal period. The data from Experiments 1 and 3 could be interpreted as supporting such a hypothesis.

Another hypothesis is that ruminative behavior may be adjunctive in nature. Following Falk's (1971) reasoning, this would require that rumination be induced by a contingency that is not operantly involved in its maintenance. There have emerged in the adjunctive literature a number of particular features guiding such a categorization. First, adjunctive behavior is defined as being dependent upon at least some degree of food deprivation (Falk, 1969). Two of the subjects in our study may be considered food deprived, at least by the criteria of subnormal body weight. Second, behavior characterized as adjunctive must occur soon after presentation of the reinforcer (Falk, 1971) unless the adjunctive behavior is not possible, in which case its occurrence shifts to the subsequent period in which it is possible (Gilbert, 1974). In addition, the frequency of the adjunctive behavior should be at or near its highest level immediately after reinforcer presentation and decrease until it ceases sometime before the next reinforcer presentation (Falk, 1971). This is indeed the characteristic distribution of ruminative responses—few or none at all during the meal and a high and then decreasing level of responding during the post-meal period. Third, increasing reinforcer size usually decreases adjunctive behavior (Falk, 1967). This is also the relation observed with ruminative behavior; when meal size increases, responding decreases in an orderly manner (Rast et al., 1984). Fourth, concurrent adjunctive patterns of behavior may be observed (Wayner & Greenberg, 1973), and, in fact, Rast et al. (1981) did measure concurrent towel-chewing behavior in one subject. Fifth, changes in the schedule of reinforcement produce changes in the distribution of adjunctive behavior (Falk, 1967; Porter & Kenshalo, 1974). No comparable manipulations have been made in the present research program.

Although these similarities suggest that ruminative behavior is adjunctive in nature, there are several differences as well: First, subjects will ruminate even when they are not food deprived by a body-weight criterion. Second, although ruminative responding is possible from the time food has been ingested, so long as a sufficient volume remains in the stomach, responding occurs less frequently after larger meals than after regular, smaller meals. Third, the intervals between episodes of eating and the amount of food consumed are quite different here than in the laboratory adjunctive literature. The intermeal intervals in the present study were measured in hours rather than seconds or minutes, and the quantities of food consumed were vastly greater in relation to body weight than for pigeons. Fourth, although some characteristics of ruminative behavior appear similar to those of adjunctive behavior, this does not necessarily mean that the same variables control them. For instance, the temporal distribution of ruminating partly depends on the presence of food in the stomach available for regurgitation, so the rapid post-meal increase and then gradual decrease in responding may be determined by the proper location of the necessary amounts of food in the digestive tract. However, there are no such temporal limitations for pigeons' attacks that also show this pattern (Azrin, Hutchinson, & Hake, 1966).

The present experiments have identified some variables (e.g., caloric intake) that, although not necessarily inconsistent with the defining features of adjunctive behavior, have no apparent role in possible adjunctive relations. Furthermore, this study has suggested possible controlling variables (oropharyngeal and esophageal stimuli functioning as reinforcers) that would violate the usual presumption that the adjunctive behavior is not reinforced (Lyon, 1982). Even if it can be clearly shown that ruminative behavior shares some of the general characteristics that have come to define the label *adjunctive*, this would constitute no more than the beginning of an explanation. Describing a performance as adjunctive constitutes only one level of explanation; it refers to a set of relations that define the term, but it does not account for them in terms of necessary and sufficient variables.

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