A PARAMETRIC ANALYSIS OF THE RELATIONSHIP BETWEEN FOOD QUANTITY AND RUMINATION

JIM RAST, JAMES M. JOHNSTON, AND CHERYL DRUM

UNIVERSITY OF FLORIDA AND SUNLAND CENTER, GAINESVILLE

Rumination is the chronic regurgitation, chewing, and reswallowing of previously ingested food. The study reported here, using a parametric design, examined the control of rumination by the quantity of food eaten at meals. The subjects were three profoundly retarded individuals who chronically emitted this behavior. The quantity of food by weight ingested daily was varied in 10-oz steps in both ascending and descending series (data were collected only after breakfasts and lunches). Ruminating decreased when food quantity increased and increased when food quantity decreased. In addition, there was a similar inverse interaction between breakfast food quantity and post-lunch ruminating. The data showed relatively rapid transitions in both frequency and duration at each meal size for all subjects. The data establish a clear functional relation between the quantity of food ingested and ruminating.

Key words: rumination, food quantity, retardation, satiation, retarded adults

Rumination is the chronic regurgitation, chewing, and reswallowing of previously ingested food. Although it occurs in otherwise normal individuals (especially young children), it is most often observed in profoundly retarded institutionalized individuals.

The research concerning rumination has focused solely on methods of controlling the behavior for therapeutic purposes. Although this is unquestionably a worthy goal, its attainment is seriously constrained by the complete lack of either behavioral or physiological research needed to identify the fundamental relationships responsible for the development or maintenance of this behavior. The basic research literature concerning the regulation of food intake (e.g., Campbell, Hashim, & Van Itallie, 1971; Jordan, 1969) does not directly address rumination, although it does suggest variables that might be the basis for preliminary experimental analysis. Although the basic operant laboratory literature has not analyzed this behavior, the fundamental processes of conditioning could figure in contingencies embedded in feeding practices. Furthermore, the characteristic distribution of ruminative responses in the immediate post-meal period raises the possibility that the behavior is adjunctive in nature (Falk, 1971), although there is no direct evidence on this point.

A first step in the experimental analysis of

rumination was taken by Rast, Johnston, Drum, and Conrin (1981) with their replication of the serendipitous discovery that the quantity of food ingested was one such variable (Jackson, Johnson, Ackron, & Crowley, 1975). Rast et al. (1981) alternated baseline phases of regular meal sizes with phases in which subjects had free access to food and consumed from three to eight times more food by weight. The effects of these manipulations were both immediate and substantial. The subjects' post-meal frequencies of ruminative responses and the cumulative duration of these responses showed rapid transitions to greatly decreased levels when the free-feeding or the satiation condition was implemented, and the effects were maintained for as long as the condition was in effect (from one to three months). When the regular meal size conditions were reinstituted, transitions were equally brief, and response measures returned to baseline levels.

This study, however, was only a preliminary demonstration of a tentative relation between the quantity of food ingested and ruminative responses, and some fairly basic questions remained unanswered. For instance, what is the parametric nature of the relation between quantity of food and ruminating? Will the effect appear gradually as the amount of food consumed across meals increases, or will the

full effect appear at some critical value of food quantity? Is there an interaction effect between meals, such as the amount ingested at one meal being related to the degree of ruminating at the following meal? The present experiment was designed to further analyze the preliminary relationship in order to answer these questions.

METHOD

Subjects

All three subjects were profoundly retarded residents at Sunland Center, Gainesville. All subjects were medically screened to determine that structural physiological conditions known to cause rumination were not present. Subject RF03 was a 22-year-old female who was blind, had a slight hearing impairment, and did not talk (although she followed familiar instructions). However, she was ambulatory, toilet trained, and had self-feeding skills. She regularly ruminated following all meals. Her weight was 78 lbs before the program, although her ideal range was 94 to 101 lbs.

Subject RM06 was a 34-year-old male who was nonambulatory, nonverbal, not toilet trained, and who engaged at times in other self-injurious behavior. He had self-feeding skills but ruminated following all meals. He weighed 77 lbs, although his ideal weight range was 103 to 114 lbs.

Subject RM01 was a 32-year-old male who, although essentially nonverbal, responded to familiar commands, was toilet trained, and had basic self-care skills. He routinely ruminated after meals and weighed 105 lbs; his ideal weight range was 132 to 145 lbs.

Setting

The experiment was conducted in a room measuring 4.6 m by 5.5 m and containing two rectangular tables and five chairs. A corner table contained weighing scales and food; the other table was located centrally and had two chairs facing each long side. Sessions for Subject RM06 and for Subject RM01 were conducted simultaneously with those of another subject. The two subjects were seated well separated on one side of the table during meals, and each subject's observer sat directly across the table. During post-meal periods RM06 and RM01 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 table.

Measurement

During the meal the observer monitored the subject's eating. During the 60-min post-meal period the observer counted each ruminative response and timed its duration (these subjects ruminated only after meals). The topography of ruminative responses was quite distinctive and stable for each subject, and topography was perfectly correlated with the functional response class definition—requiring food in the mouth that came directly from and went back to the stomach and esophagus. Duration was timed from the moment food was regurgitated to the mouth to the moment it was reswallowed. Response frequency and total response duration were calculated for each session. Calibration procedures were followed in training and assessing all observers (Johnston & Penny-packer, 1980). After an observer's training was completed and his or her service was underway, several sessions in each phase for each subject were videotaped from inside the session room. Each videotape was then viewed by the senior author as many times as necessary with the benefit of stop action in order to obtain the true values of count and total duration for that session. The correspondence between these values and the observer's values yielded a degree of accuracy that did not necessitate any observer retraining. Table 1 shows these data.

In addition, interobserver agreement data were obtained by having an extra trained observer present for a number of sessions in each phase for each subject. These data also are shown in Table 1.

Table 1

Calibration and interobserver agreement data for all subjects.

Procedure	Subjects	No. Sessions	% Correspondence	
			Frequency	Duration
Calibration	RF03	18	94-100	92-100
	RM01	14	92-100	93-100
	RM06	14	93-100	91-100
Inter-Observer	RF03	33	94-100	91-100
	RM01	28	93-100	89-100
	RM06	29	80-100*	93-100

*Only one agreement was below 92%.

Experimental Procedures

Experimental sessions were conducted at breakfast (7:00 a.m.) and lunch (12 noon) on weekdays. At dinner (5:00 p.m.) the subjects received meals of the same quantity and food types as at lunch. However, they ate the dinner meals with the other residents in their cottage, and no observations were made. Weekend meals were also of the same quantity and type as meals on the preceding experimental day.

All meals consisted of the standard institutional diet. They were measured by the dietary staff and were weighed by the observer. Once a week the foods were weighed a second time by an additional observer (during 125 such checks, no discrepancies exceeded 1 oz).

Breakfasts usually consisted of fruit juice, egg, white bread, and hot cereal. Lunches included milk, diced meat, green vegetable, starch, and fruit. The liquids (always 4 oz of fruit juice for breakfast and 8 oz of milk for lunch) were consumed before the solid food and were not part of the parametric manipulations of food quantity. The increased portions of food beyond baseline amounts were in the form of starches, including potatoes, rice, grits, cream of wheat, and bread.

At experimental meals the subject was seated at a table and given the liquid portion of the meal first. While the subject ate, the observer refilled the plate until the entire scheduled amount of food was used. A meal was considered completed when all the food was consumed or when the subject emitted three consecutive "meal completion responses" without intervening eating. These responses were setting the spoon down, spitting out food, or getting up from the table. The food tray was then removed, and the 60-min observation period began at this point.

Subjects RF03 and RM01 received an ascending series of food quantities by weight, with the final condition being a return to the baseline quantity. After an initial baseline condition of standard food quantity, Subject RM06's series began with large quantities and decreased until the baseline levels were again reached. The weights of meals in each phase were staggered across breakfast and lunch in order to detect any effects of the breakfast meal on post-lunch responding. The weights for breakfasts and lunches for each phase are indicated in the figures.

RESULTS

The data describe a functional relation that may generally be characterized as inverse; that is, increases in meal size are related to decreases in ruminating, and decreases in meal size are related to increases in ruminating. The relation was consistent between the parametric extremes of normal portions of standard institutional diet to satiation levels attained by supplementary foods high in starch and at parametric steps of 10-oz differences. Furthermore, the relation was the same in both descending and ascending series. Not only did each subject show a change in responding at each parametric level, the amount of the change was generally consistent within phases and roughly proportional across subjects. The only exception to this consistency was itself consistent: the slight increase in post-breakfast responding correlated with a baseline-plus-10-oz food quantity observed with both RF03 and RM01 and the comparable effect observed with RM06 after both meals in the baseline-plus-10-oz phase prior to the final baseline condition.

Figure 1 shows the frequency and duration of responding for Subject RF03. In order to illustrate transitions between phases as well as stable responding, all the data are shown except for some of the longer phases, for which only the first and last two weeks of data are given. The upper semi-logarithmic graph shows responding after breakfast meals and the lower graph shows post-lunch responding. The graphing conventions are those of the Standard Behavior Chart (Pennypacker, Koenig, & Lindley, 1972). Thus, frequencies plotted below the .016 line and durations plotted above the 1.0 (right vertical axis) mean that no responses were observed in the 60-min post-meal period. Furthermore, it should be noted that scale values on the right vertical axis represent shorter durations with higher positions on the axis.

Figure 1 shows that under the baseline condition of standard portions (6 oz at breakfast and 16 oz at lunch, not including liquids), this subject ruminated after breakfasts at rates of about 0.7 to 1.0 per min with aggregate durations of 6 to 18 min. Frequencies and durations were slightly higher after lunches.

Between the baseline and the second phase shown in Figure 1, the subject was exposed to a 3-week phase in which she received 10 oz more food at all meals and then a 1-week phase

Fig. 1. Frequency (filled circles, left vertical axis) and total duration (unfilled circles, right vertical axis) of responding during 60-min post-meal observation periods for Subject RF03 across all experimental conditions for breakfast (top graph) and lunch (bottom graph) meals. The breaks in the horizontal axis and the number above indicate the location and number of days of omitted data. Note that scale values on the right vertical axis, representing duration, decrease going up the axis.

of 20 oz more than baseline at all meals. Data from these redundant conditions were similar to those presented here and have therefore been omitted in the interest of brevity.

In the second reported phase, 10 oz of starches were added to all meals (totaling 16

oz at breakfast and 26 oz at lunch; as always, dinner meal sizes were the same as lunches). Both rumination frequency and duration increased slightly after breakfasts and decreased slightly after lunches. This reproduces the effects observed under similar conditions by

Rast et al. (1981) in which a slight increase in food quantity at breakfast was correlated with a slight increase in responding.

In the third phase, the quantity of food consumed at breakfasts was held constant at 10 oz above baseline while the lunch quantities were increased to 20 oz above baseline amounts (totaling 36 oz). The data showed no changes in the levels of responding after breakfasts but decreased to about 0.6 responses per min and 6-min total duration after lunches. Furthermore, these changes in responding occurred after the first lunch meal in this phase and remained relatively stable for its duration.

In the following phase, the lunch quantities were held constant and the breakfast quantities were increased to 20 oz above baseline amounts (totaling 26 oz). There was an immediate decrease in both frequency and duration measures in post-breakfast sessions; the number of responses in the 60-min sessions dropped from approximately 75 to 45, and their accumulated durations dropped from approximately 14 min to 6 min. However, even though the lunch food quantities did not change from the previous phase, there was an immediate, large, and sustained decrease in post-lunch responding. In fact, on a number of days there was little or no ruminating. This decrease in post-lunch responding correlated with an increase in the breakfast food quantities suggests an interaction effect between meals that may explain the slight decrease in post-lunch responding observed in the second reported phase.

This interaction is further supported by the data from the next phase. Here lunch quantities were again held constant at plus 20 oz while breakfast quantities were finally increased to the same level (plus 30 oz or a total of 36 oz). After breakfasts the response measures initially decreased sharply but quickly recovered to a stable level slightly lower than the previous phase. However, responding after lunches occurred in only two sessions, even though lunch quantities had not been changed.

In the last two ascending phases, lunch quantities remained at plus 20 oz while breakfast quantities were increased to 40 oz and then 50 oz above baseline. Ruminative responses occurred only twice after one lunch (in one of the sessions not shown) during the first of these phases. The plus-40-oz breakfast condition

yielded further decreases in frequency and duration measures, and little or no responding occurred on a number of days. No responding at all occurred under the plus-50-oz condition.

This phase was followed by a return to the 6-oz breakfast, 16-oz lunch baseline condition. The frequency and duration of responding immediately increased to near baseline levels after both meals, followed by a slight and gradual transition to levels at (lunches) or slightly above (breakfasts) the original condition.

Figure 2 shows the data for a similar parametric series for RM01. Under baseline quantities (6 oz at breakfasts and 16 oz at lunches) his frequencies and durations were only marginally lower than for RF03 at both meals. When 10 oz of food was added to both meals, responding again increased slightly after breakfasts and decreased slightly after lunches. The addition of 20 oz to each meal (a total of 26 oz at breakfasts and 36 oz at lunches) was correlated with a marked decrease in both measures after breakfasts, but an even larger decrease after lunches; in fact, there was little or no ruminating after a number of lunch meals.

This interaction between breakfast food quantities and post-lunch responding was further clarified in the following phase, which held the lunch (and dinner) quantities constant but increased the breakfast amounts by 10 additional oz. Response measures after breakfasts declined further, but so did post-lunch measures. Adding a final 10 oz to lunches (and, as always, dinners) in the next phase quickly eliminated post-lunch responding, but responding in the breakfast sessions also declined further, perhaps due to interaction effects from the dinner meals the previous evening. When the baseline meal sizes were reintroduced in the final phase, responding immediately increased after lunches to a stable level lower than originally observed. Post-breakfast responding did not occur until the third session, although the transition to near baseline levels was then fairly rapid.

In summary, the data for RM01 show the same effects of meal size as observed for RF03. Although his data were slightly more variable, the transitions at the beginning of each phase occurred immediately (with the exception of the final breakfast baseline condition), and the same interaction between breakfast food quantities and post-lunch responding was observed.

RM06 was exposed to a descending para-

Fig. 2. Frequency (filled circles, left vertical axis) and total duration (unfilled circles, right vertical axis) of responding during the 60-min post-meal observation period for Subject RM01 across all experimental conditions for breakfast (top graph) and lunch (bottom graph) meals. The breaks in the horizontal axis and the number above indicate the location and number of days of omitted data. Note that scale values on the right vertical axis, representing duration, decrease going up the axis.

RM06 BREAKFAST

RM06 LUNCH

Fig. 3. Frequency and total duration of responding for Subject RM06 across all experimental conditions for breakfast (top graph) and lunch (bottom graph) meals. Note that scale values on the right vertical axis, representing duration, decrease going up the axis.

metric series of food quantity. The baseline condition was 16 oz at breakfasts and 26 oz at lunches, and it is clear that this subject ruminated at a higher frequency and for a longer aggregate duration than did RF03 or RM01. In the second phase the subject received 46 oz at breakfasts and lunches (30 oz and 20 oz over baseline quantities, respectively), and responding immediately ceased entirely. In the next phase, the breakfast quantities remained unchanged while the lunch amounts were decreased to 10 oz above baseline. The increase in responding after lunches was again immediate, and the level varied widely from little or no ruminating to five or more responses per min. The unexpected observation was that after one week, responding in post-breakfast sessions also increased. This may have been related to the decreased dinner meal size the previous evenings; however, the dinner-breakfast interval was 14 hr, whereas the breakfast-lunch interval already clearly related to an interaction effect was only 5 hr.

In the following phase, lunch quantities remained the same (plus 10 oz) and breakfast quantities were decreased 10 oz, so that the subject consumed 26 oz at each meal. Not only did post-breakfast responding immediately increase to stable intermediate levels, but post-lunch responding did likewise. When 10 additional oz were eliminated from the breakfast meals in the next phase, the amount of ruminating immediately increased further to levels slightly higher than the original baseline levels. Again, even though lunch meal sizes did not change, responding increased to the same higher-than-baseline levels. In the final phase both meal sizes decreased by 10 oz to baseline levels, and both response measures decreased slightly after both meals to the point of matching the levels originally observed.

DISCUSSION

These parametric manipulations of the quantity of food ingested were designed to clarify the nature of its relation to rumination (reported by Rast et al., 1981) and to begin an analysis of that relation. These data show the relation to be quite reliable; responding of all subjects changed in the same manner and to the same general degree when meal sizes were varied. Any differences among subjects were only in the levels of responding, and the para-

metric series showed the same functional relations across all three subjects. The relation was inverse in nature and was equally clear in descending and ascending series of variations in food quantity.

Especially notable were the immediacy with which transitions usually began after a change in meal size, the brevity of the transitions, and the stability of responding under each condition. The frequency and duration of responding often changed after the very first meal at a different food quantity, and changes were almost always evident within the first sessions. Furthermore, the magnitude of these early changes in responding was usually large; one or more of the first few data points were often at the level observed late in the phase. Finally, the stability of ruminative responding was also significant. Taking into account the effects of the log axes on the graphic pattern, both response measures showed the least variation at the parametric extremes; even at the intermediate food quantity values, however, there was not usually any consistent trend.

Both session frequency and aggregate duration were recorded because they describe different dimensions of the response class. The correspondence between the two dimensions was generally quite good for all subjects, but the correlation was certainly not perfect. A point-by-point examination of the measures of each session shows many instances in which only one measure changed or both measures changed to different degrees, although these discrepancies are not large. Of course, neither dimension is more important than the other; they simply describe different aspects of the response class.

The reason for staggering the parametric changes in food quantity across the breakfast and lunch meals was to detect possible interaction effects, and they were clearly and reliably observed. Lunch quantities remained constant across five successive phases for RF03, across two phases for RM01, and across three phases for RM06 while breakfast quantities were stepped up or down in 10-oz amounts. Post-lunch ruminating in these phases reliably changed as breakfast quantities changed (except in the last two such phases for RF03 who had already ceased responding). This suggests an interaction effect of breakfast meal quantity on post-lunch ruminating, although the effect could be more unambiguously interpreted had

there been reversal conditions in the ascending or descending breakfast series.

Unfortunately, logistical constraints prevented incorporating the dinner meal in this design; its size was always the same as the lunch size. However, it is possible that the decrease in post-breakfast responding for RM06 in the third phase, when breakfast amounts were unchanged but lunch amounts were decreased by 10 oz, was related to the associated 10-oz decrease in dinner size the evening before. This was the only occasion to examine this possibility.

The interaction effect is important because it must be accommodated in experimental procedures and designs so that it will not be compounded with the direct effects of experimental variables and lead to misinterpretations of data. It is interesting because it would seem to be a characteristic of whatever variable or variables underlie the basic relation between food quantity and rumination. It would be appropriate to examine both the temporal and food-quantity parameters of the decay of one-meal effects on ruminating after the subsequent meal, but such a study would clearly require complete control over the distribution of the entire daily diet.

Having identified the basic relation between the quantity (by weight) of food ingested and ruminating (Rast et al., 1981) and having established in the present study the functional relation and some of its features, the task is now to identify those variables that influence the relation. In one direction, experimenters must investigate those aspects of food quantity that are necessary to maintain the relation. When the quantity of food consumed is changed, a number of potentially important variables also change, including, for example, the caloric value of the meal and the volume of the meal. In addition, the viscosity of the foods can be varied, and the nature of the foodstuffs can be altered along a number of nutritional dimensions. In the present study the amounts of food above baseline levels were starches, and it is unknown whether this is a critical variable. However, Rast et al. (1981) compared a diet prepared without tomatoes and with minimal fat to a standard institutional diet and discovered no differential effects of the two diets. The viscosity of the foods has also been manipulated in pilot work with no clear effects.

Although food may influence behavior in ways that do not require the process of conditioning, another experimental direction is more traditional—that of treating food as a stimulus in the three-term contingency. For instance, the procedure used here entailed a direct relation between the amount of food consumed and the amount of oropharyngeal stimulation. Ball, Hendricksen, and Clayton (1974) suggested that this stimulation might function as a reinforcer, and casual observation supports this hypothesis. From this perspective, food would therefore function as part of a complex of discriminative stimuli that would also include stimuli originating from stomach distention and other post-meal physiological stimuli, and the interoceptive stimuli from ruminating food would function as reinforcers. However, since the stimulation can presumably be produced after large as well as small meals, why does responding tend to occur less frequently after large meals? Even if the large amount of chewing and swallowing necessary to consume a large meal temporarily diminishes the reinforcing effectiveness of these stimuli, the larger quantity of food available in the stomach for a longer period of time might be expected to yield a somewhat delayed pattern of responding. This possibility has been examined with some subjects but has not been detected.

Another possibility is that ruminating is adjunctive in nature (Rast et al., 1981). It does consistently occur after (and sometimes during) regularly scheduled meals, but this fact alone is not sufficient to warrant such a contention (Falk, 1971). For ruminating to be assigned adjunctive status, its control by meal-time food consumption would have to be established in the absence of influence by the nutritional (biochemical) and the mechanical effects of food and in the absence of any direct reinforcement of ruminating. It would also have to be sensitive to the scheduling of meals. The present study does not provide the conditions necessary for assessing such inferences.

In any case, the role of conditioning in the development and maintenance of ruminating remains a viable experimental question. The additional categories for the processes by which food controls ruminating are biochemical and mechanical. Biochemical variables concern the nutritional properties of the foods, and mechanical variables include structural aspects

of the digestive system that are affected by non-nutritive qualities of food. Experimental analysis of several such relations is currently underway, to identify further the sources of this interesting behavior.

REFERENCES

- Ball, T. S., Hendricksen, H., & Clayton, J. (1974). A special feeding technique for chronic regurgitation. *American Journal of Mental Deficiency*, 78, 486-493.
- Campbell, R. G., Hashim, S. A., & Van Itallie, T. B. (1971). Studies of food-intake regulation in man: Responses to variations in nutritive density in lean and obese subjects. *New England Journal of Medicine*, 285 1402-1407.
- Falk, J. L. (1971). The nature and determinants of adjunctive behavior. *Physiology and Behavior*, 6, 577-588.
- Jackson, G. M., Johnson, C. R., Ackron, G. S., & Crowley, R. (1975). Food satiation as a procedure to decelerate vomiting. *American Journal of Mental Deficiency*, 80, 223-227.
- Johnston, J. M., & Pennypacker, H. S. (1980). *Strategies and tactics of human behavior research*. Hillsdale, NJ: Erlbaum.
- Jordan, H. A. (1969). Voluntary intragastric feeding: Oral and gastric contributions to food intake and hunger in man. *Journal of Comparative and Physiological Psychology*, 68, 498-506.
- Pennypacker, H. S., Koenig, C. H., & Lindsley, O. R. (1972). *Handbook of the standard behavior chart*. Kansas City, KS: Precision Media.
- Rast, J., Johnston, J. M., Drum, C., & Conrin, J. (1981). The relation of food quantity to rumination behavior. *Journal of Applied Behavior Analysis*, 14, 121-130.

Received October 14, 1983

Final acceptance November 16, 1983