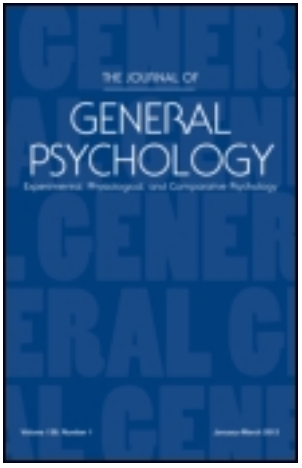

The Journal of General Psychology

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/vgen20

Reversal of Food Preferences of the White Rat Through Controlled Pre-Feeding

Paul Thomas Young [a]

[a] Department of Psychology , University of Illinois

Published online: 04 Nov 2012.

To cite this article: Paul Thomas Young (1940) Reversal of Food Preferences of the White Rat Through Controlled Pre-Feeding, The Journal of General Psychology, 22:1, 33-66, DOI: 10.1080/00221309.1940.10544318

To link to this article: http://dx.doi.org/10.1080/00221309.1940.10544318

The Journal of General Psychology, 1940, **22**, 33-66.

REVERSAL OF FOOD PREFERENCES OF THE WHITE RAT THROUGH CONTROLLED PRE-FEEDING*

Department of Psychology, University of Illinois

PAUL THOMAS YOUNG

A. INTRODUCTION

The work described in this paper has grown out of previous published studies. Our present problem, dealing with the experimental control of food preferences of rats, can be best understood by brief reference to these experiments.

In two former experiments using the preference technique (1, 2), we found among other things that rats uniformly preferred cane sugar (*S*) to ground whole wheat (*W*). In the first experiment (1) a group of eight rats and in the second (3), ten exhibited definite and strong preferences for *S*.

Subsequently a different technique was employed (4). Two food-cups, containing sugar and wheat respectively, were made to revolve slowly around a common center while the rat, who was supported upon a wire-mesh feeding-table, had free opportunity to eat from either cup. The number of seconds which the rat gave to eating from each of the cups was counted electrically.

Cumulative eating times for *W* and *S* were compared—first for ten minutes, then five, and finally for 100 eating-seconds. With a 10-minute test *S* was eaten in about 36 per cent of the time; with a 5-minute test *S* was eaten in about 47 per cent of the time; but with a period of 100 eating-seconds the greater proportion of time, 59 per cent or more, went to *S*. The percentages varied from day to day, but the results made it clear that the proportion of the total eating time given to *S* was not constant but varied with the duration of the test.

Hence, if *relative eating time* is used as a criterion of preference, the duration of the test must be specified and rigidly controlled. Only when the eating times were kept down to 100 seconds or less did results with the revolving-cup technique agree with those obtained by the preference method.

*Received in the Editorial Office on November 5, 1938.

The discrepancy between results gained by the two experimental methods can be cleared up by assuming that food preferences change during a period of eating. With a "brief-eating" preference test one result may be found, but with a test involving a longer period of eating the result may be different.

Starting from the above experimental results, we developed an hypothesis to explain them. This hypothesis is illustrated in Figure 1 and described below. Before considering it the reader should be warned that the present experiment itself has cast some doubt upon the assumption of a single continuum of demand. The argument, however, is given as it was first developed.

Consider Figure 1. The vertical at the left represents a continuum

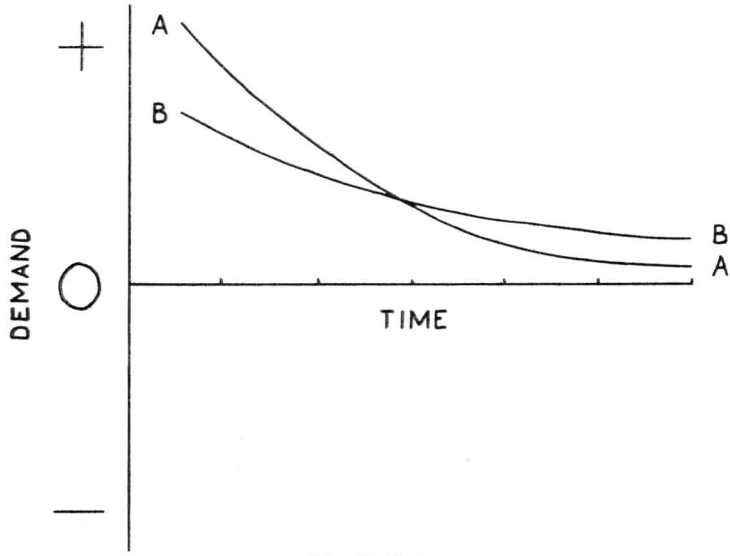

FIGURE 1

CHANGING DEMAND FOR TWO FOODS WITH THE APPROACH TO SATIATION

of demand from highest craving through indifference to greatest aversion. The horizontal represents the duration of eating in arbitrary time units. The curves picture the assumed decrements in demand for two foods as a rat eats continuously, approaching satiation.

The rat, we assume, is given a choice between two foods, *A* and *B*. One of them, *A*, is at first definitely preferred to *B*. But with continuous eating, the animal becomes quickly satisfied with *A*, whereas with *B* the gradient of approach to satiation is more gradual. After a period of continuous eating the demand for *B* will be relatively higher than that for *A*, owing to *A*'s more rapid approach to satiation. Thus if a preference test is given which involves relatively brief periods of eating, a preference of *A* to *B* will be indicated; but if more prolonged periods are utilized, the initial choice will be obscured and a preference of *B* to *A* will be shown by the longer, cumulative test-times.

In short, the difficulty encountered with cumulative time as a criterion of preference is this: it may obscure mutations of preference, and may give results which vary with the duration of the test itself.

Now, the implications of Figure 1 can be examined experimentally. By allowing a rat to eat sugar immediately before each preference test and varying systematically the time allowed him for eating it, we should be able to control his demand for sugar and to detect changes in test results. Such periods of preliminary feeding just before a preference test we have called *pre-feeding* periods, and their duration we have designated the *pre-feeding* time.

In planning the present experiment we aimed first to repeat our original preference study with a group of typical rats to determine again the preferential rating of sugar relative to wheat, and then to pre-feed sugar and wheat for controlled periods of time to examine the effect of such pre-feeding upon preference.

We turn now to the experiment itself but will refer later to the conception of demand implied in Figure 1.

B. Conditions and Plan of the Experiment

1. *Subjects*

Twelve albino rats, from Wistar Institute stock, five males and seven females, were used as subjects. One of these proved to be so slow and timid that she was dropped after the first series, and for the rest of the work 11 rats were employed. During the experiment the rats varied in age from 25 to 69 days.

2. *Diet of Rats*

After weaning they were placed upon a diet consisting of Purina dog checkers which had been ground to a fine powder.[1] They were given from time to time small pieces of lettuce or raw spinach leaf. Tap water was furnished at all times. During the experiment and for a few days before it the rats were fed in individual cages. They were fed in the late afternoon following a period of experimenting.

The rats were weighed every few days. Weights at weaning are shown in Table 1 along with other data upon the subjects.[2]

3. *Food-Preference Apparatus*

The plan of the apparatus has been described elsewhere (1, 2); details need not be repeated here. In general, the preference apparatus consists of a retaining box with a door through which a rat can pass over a run-way to a round, wire-mesh feeding plate. Presented at an opening in the center of the plate are two glass tubes, each leveled off to the top with a test-food.

An essential feature of the apparatus is an elevator device for raising the foods to the feeding plate and for lowering them out of the animal's reach after a choice has been made. The elevator carries a turn-table by a 180° rotation of which the relative positions of the test-foods can be interchanged. There is also a sliding

---

[1]The chemical analysis of this laboratory chow, furnished by the Ralston Purina Co., of St. Louis, Mo., is:

	Crude	Digestible
Protein	23.0%	19.0%
Fat	5.0%	4.7%
Fibre	4.0%	
Ash	7.0%	
Nitrogen-free extract	54.0%	48.0%
Moisture	7.0%	
	100.0%	71.7%

The chow contains the necessary vitamins. The salts are iodized. The mineral analysis is:

Iron	0.018%	Sodium	0.67%
Magnesium	0.09 %	Chlorine	0.68%
Silica	0.23 %	Phosphorus	1.17%
Potassium	0.56 %	Calcium	2.22%

[2]The writer acknowledges help and advice, concerning the care and handling of the animals, which was kindly given by Dr. W. G. McAllister.

TABLE 1
DATA UPON RATS

Litter	Rat	Sex	Date born	Weight at weaning (gr.)	Age range during experiment (days)
1	2	M	4/12/38	39	41-69
1	4	M	"	41	"
2	10	M	4/14/38	55	39-67
3	14	F	4/15/38	34	38-66
3	15	F	"	35	"
4	20	F	4/19/38	45	34-62
5	22	M	4/20/38	51	33-61
6	24	F	4/21/38	33	32-60
6	29	M	"	33	"
7	44	F	4/28/38	37	25-53
7	45	F	"	46	"
7	46	F	"	44	"

plate which automatically closes the opening in the feeding table when the foods are lowered.

In preparing the apparatus for the present experiment standard pyrex glass tubes of 16 mm. outside diameter and 13 mm. inside diameter were cut into pieces 15 cm. long. The ends were ground even and fused to prevent possible injury to the animal while eating. Cotton plugs were inserted into the bottom of these tubes to hold the sugar or wheat in place.

The distance between exit of the retaining box and center of the food tubes was 38 cm., slightly less than in previous experiments. Incidentally, this measure should be kept constant from experiment to experiment if running activity is to be compared; we propose henceforth to standardize the distance at 38 cm.[3]

4. *Procedure with the Food-Preference Apparatus*

The animals, individually, were given preliminary training on the

[3]The preference apparatus could be improved by adding a removable catch-tray for food and feces just beneath the wire-mesh floor. This could be made to extend beneath the run-way so as to prevent the occasional escape of an animal at this place. Also a cover could be added to prevent the animal from climbing over the sides during exploration.

Another suggested modification is the addition of a water bottle to the retaining box.

preference apparatus. At first each rat was placed on the apparatus for 30 to 60 minutes of exploration. The next day the following conditions were adhered to rigidly:

1. The rat was placed in the retaining box. The food was adjusted by raising the cotton plug in the bottom of the glass tube and leveling it off at the top.

2. The food-elevator was raised and the door to the retaining box opened. The door was kept open until the rat had discovered the food, eaten and returned to the box.

3. When the rat first made contact with the test-foods he was given several seconds to eat. During training and when the animal was obviously attempting to discriminate between foods an exposure of several seconds was found to be desirable; but after training, foods were removed and the opening automatically closed as soon as the rat had taken the first nibble.

4. Following feeding, the experimenter waited until the rat returned to the retaining box, then closed the door.[4]

5. After this or while the rat was returning to the retaining box the experimenter recorded the observation, reversed the positions of the foods, adjusted the food level, cleaned the apparatus, raised the foods to the table and then proceeded as above for the next trial.

Rats soon learn the shuttle pattern on the preference apparatus. After a few days of practice the animals run back and forth about as rapidly as the experimenter cares to operate the apparatus.

Progress in learning is indicated by the total number of runs from day to day. With the group of 12 rats during four days following some preliminary training, the total number of runs made in successive periods of exactly 15 minutes was:

Day	*Runs*
1	183
2	308
3	413
4	522

[4]It takes the rat longer to learn to go back into the box than to learn to come out for food. This difference, incidentally, should be expected on the basis of Hull's goal gradient hypothesis.

5. *Data Sheets*

Records were kept on mimeographed sheets. Each sheet contained a dotted line for recording: (*a*) the number of the rat, (*b*) the test-foods used in the preference series, (*c*) the date and hour of observation, (*d*) the food located at the *experimenter's* right on Trial 1, and (*e*) 50 dotted lines arranged in two parallel columns and numbered consecutively from 1 to 50 for recording observations.

Item *d*, the food located at *E*'s right on Trial 1, furnished a key to the spatial positions of foods throughout the entire series. If sugar is at *E*'s right on Trial 1, it was also at his right on all odd-numbered trials, and at his left on even-numbered. We found that frequent reference to this key was at first necessary to keep the alternations in order.

6. *Apparatus for Pre-Feeding*

The pre-feeding cage was an ordinary square box with wooden floor and top, 20×30 cm., and sides, 15 cm. high, made of wire-mesh. Food was presented in open glass containers. Both cage and containers were cleaned daily after every experiment. A water nozzle inserted through the side made water accessible at all times.

7. *The Pre-Feeding Technique*

Conceivably we could control pre-feeding in terms of the number of grams of food ingested; but if we were to weigh out a given quantity of food and present it to the rat, especially with larger quantities, the animal might fail to eat it. But apart from this practical difficulty, there is a more serious theoretical objection to the use of weight of food as a means of controlling pre-feeding. The total weight of food consumed by an animal during a period of eating does not indicate changes in the animal's demand during that eating period.

Although students of nutrition for purposes of their own have depended upon the weight of food ingested, the total weight of food eaten during a given time is just as ambiguous as the total eating time when it is considered as a criterion of demand.

We have depended upon precise timing. A rat was placed in a pre-feeding cage. At the instant when he began to eat, the experimenter pressed a silent key which started a Telechron clock. When

the rat stopped eating to explore, preen, drink, or rest, the key was released. This cumulative timing made it possible to remove a rat from the pre-feeding box when he had eaten exactly 100 seconds, or after some other pre-determined period.

In one series we placed a rat in the feeding cage for exactly 15 minutes, letting him eat all the sugar he would during this period, but without timing the total number of eating-seconds. Further details of the pre-feeding technique will be presented with the results.

8. *Plan of the Experiment*

The experiment as a whole is made up of five consecutive series. In presenting results we will take up the five series in chronological order and then survey the total investigation.

The five series with their inclusive dates (all in the spring of 1938) are:

Series I. The preference of sugar to wheat; daily 15-minute preference tests, May 28 to June 4.

Series II. Pre-feeding sugar and wheat for 100 eating-seconds, followed by 15-minute preference tests, June 5 and 6.

Series III. Pre-feeding sugar and wheat up to 400 eating-seconds, followed by *5-minute* preference tests, June 7 to 9.

Series IV. Reversal of the sugar-wheat preference through pre-feeding sugar for 15 minutes, followed by 15-minute preference tests, June 10 to 15.

Series V. The restoration of sugar preference by omitting the pre-feeding; daily 15-minute preference tests as in Series I, June 16 to 20.

C. Criteria of Preference

In presenting our results it will be necessary constantly to refer to preference and to the absence of preference. Consequently the criteria used to detect preference are of importance, and will be described before actual results are given.

Preference cannot be shown by a single trial. The true unit in a preference experiment is the sequence of *two* consecutive trials in which relative positions of the test-foods are interchanged. We have come, however, to rely upon three such double units, or six consecutive trials in determining preference.

In a previous study (1, 4) we described three criteria of preference as follows:

1. *When one and the same food is taken by an animal exclusively for six or more consecutive trials the animal prefers the food taken.*
2. *When one and the same food is taken by an animal in six or more consecutive trials and when the second food is touched (eaten or tasted) in not more than half of these trials the animal prefers the food taken in every trial.*
3. *The food having the greater number of univocal eatings in any sequence of six or more consecutive trials is preferred.*

Application of these criteria is illustrated by the following sequences in which *A* and *B* symbolize any two foods:

A	A	AB	A
A	BA	A	B
A	A	AB	A
A	BA	A	A
A	A	AB	A
A	BA	A	B

The pattern at the extreme left shows preference for *A* by Criterion 1. The second and third patterns (the third is actually quite rare) indicate preference for *A* by Criterion 2. The last pattern gives preference for *A* by Criterion 3. In making a count equivocal records, such as *BA* and *AB* in the second and third patterns, are counted as ½ for *A* and ½ for *B*.

By contrast, the following patterns are ambiguous, showing no preference:

A	AB	AB
B	BA	AB
A	AB	AB
B	BA	AB
A	AB	AB
B	BA	AB

The pattern at the left is common; it occurs when behavior is spatially determined without discrimination between the foods. The second pattern occurs less frequently. We have referred to this pattern as the *sampling reaction* because when the single observation is extended the rat continues to eat the foods alternately. The third

pattern is rare and transitional; it is less stable than the other two.

In appraising our data we drew a straight line in the margin of the data sheets beside all consecutive records which indicated preference either by Criterion 1 or by Criterion 2. In a sense, Criterion 2 is not so severe and demanding as Criterion 1, but this difference has generally been ignored in presenting results.

For one or two special purposes we made use of Criterion 3.

In applying the criteria of preference we have disregarded the numerous instances of sniffing and smelling the test-foods, and limited consideration to the actual contacts which an animal made with the foods. These contacts were of two main kinds: nibbling, i.e., actually eating a food (recorded by capital letter) and tasting, i.e., merely touching a food with the tongue but without ingesting any (recorded by small letter). It was not always possible to distinguish clearly between these two kinds of contact. Consequently in working up the data we have treated records in the form *AB*, *BA*, and those in the form *aB*, *bA*, alike as ambiguous dual-contacts.

We turn now to results from the five series.

D. Results

Series I: The Preference of Sugar to Wheat

Series I consisted of 200 trials per rat, except for timid rat No. 20 who completed only 100 trials (see p. 35).

A summary of results is presented in Table 2 which should be

TABLE 2

Summary of Series I Showing Preference of Sugar to Wheat

Rat	=	$S > W$	Comment
2	1-19	20-200	
4	1-66	67-200	
10	1-72	73-200	trial 99 W
14	1-70; 76-79	71-75; 80-200	
15	1-20	21-200	
20	1-20; 28-31; 53-63	21-27; 32-52; 64-100	100 trials only
22	1-13	14-200	
24	1-30	31-200	
29	1-14	15-200	trial 72 W
44	1-50	51-200	trials 55, 59, 86 W
45	7-31	1-6; 32-200	
46	1-8	9-200	

read as follows: Rat No. 2 failed to meet the criteria of preference during the first 19 trials; he revealed a clear preference of *S* to *W* in every trial from 20 to 200 inclusive. Again, rat No. 10 failed to show any definite preference during the first 72 trials, but chose *S* in preference to *W* in every test from 73 to 200 with the single exception of a wheat choice in Trial 99.

Table 2 shows that the rats all started the series with indiscriminate, non-preferential behavior, symbolized by " = ," and that they ended the series with consistent *S* preference. For Trials 101-200, inclusive, all rats revealed *S* preference by Criterion 1 except for the following which gave *S* preference by Criterion 2: Rat 24, Trials 101-200, Rat 29 about 40 trials, Rat 14, 6 trials. This distinction between Criteria 1 and 2 is not, as we have noted above, indicated in Table 2.

The preferential favoring of *S* was uniform, consistent, clean cut. The rats revealed *S* preference even more convincingly than did the animals of our previous investigations. Without exception the trend of all animals was toward *S*. At no time in the series did a rat even once meet the criterion for *W* preference.

Such equivocal behavior as appeared was for the most part determined by spatial relations. The posture of a rat after he had approached the food favored either the right or the left position. Rat No. 2 was inclined weakly to eat the food at his right; the others were more or less strongly biased toward the left. This frequent bias toward the left might have occurred through a chance selection of subjects, but it is possible that some constant factor in the apparatus favored the position at the rats' left.

The way in which equivocal behavior developed into a clear expression of *S* preference is a matter of some interest. The following stages are typical:

I	*II*	*III*	*IV*
S	S	S	S
W	WS	wS	S
S	S	S	S
W	WS	wS	S
S	S	S	S
W	WS	wS	S

In Stage I the pattern is spatially determined; there is no prefer-

ential discrimination between foods. In Stage II the initial eating is spatially determined, but on the even-numbered trials the rat turns from *W* in the favored position to *S* in the unfavorable position, whereas this desertion does not occur on odd-numbered trials which have *S* in the favored position. In Stage III instead of actually nibbling or sampling *W* on trials 2, 4, 6, the rat merely tastes the food, i.e., touches his tongue to it, and turns to *S*. Tasting of *S*, when it occurs, is not followed by turning to *W*, but rather by further eating of *S*.

Stages II and III clearly indicate *S* preference by Criterion 2. Sometimes tasting is supplanted by smelling, i.e., sniffing at the food without contact; but since our present interpretation of preference is based upon *contact* with the food, olfactory exploration is not here indicated.[5]

Finally, in Stage IV, the rat runs directly to the foods and eats *S* without preliminary tasting and apparently without even smelling. The choice is so immediate and consistent that we assume vision, through conditioning, has come to furnish the sensory cues for discrimination. Stage IV is that of *S* preference by Criterion 1. A rat does not necessarily pass through all of these stages in developing a preferential discrimination, but we have repeatedly observed some or all of them in the emergence of *S* preference from indiscriminate eating.

Rats 2 and 20 to an appreciable extent revealed the pattern which we have previously called the sampling reaction or alternate eating. In this reaction the animal rapidly eats the test-foods in alternation for the duration of their exposure. The record for a single trial shows: *SWSWSW*. . . . The pattern is indeterminate; but possibly precise timing might indicate a preference for one of the foods. Sometimes one of the foods clearly has an emphasis in time which presages a transition to unmistakable preference.

To summarize, all rats started the series with indeterminate behavior patterns and all developed a marked and consistent preference of sugar to wheat; no rat at any time indicated a preference for wheat.

[5]In addition to recording the animals' smelling and sniffing at the food, we also recorded exploratory behavior on the apparatus, periods of inactivity and bursts of activity, defecation, eating of feces, grabbing the food-tube with the paws, and other activities; but most of these secondary observations have not been utilized in the present report.

Series II: Pre-Feeding Sugar and Wheat for 100 Eating-Seconds

Immediately following the completion of Series I the rats were pre-fed sugar and wheat for 100 eating-seconds.

The technique of pre-feeding has been described above. A rat was placed in the pre-feeding box and timed by a Telechron clock until his cumulative eating time equalled exactly 100 seconds; he was then removed and placed at once upon the preference apparatus for a 15-minute test.

The time required to complete the 100 seconds of pre-feeding is given in minutes in Table 2A. In general, more time was required to pre-feed *S* than *W*.

TABLE 2A

Rat	Pre-feeding *S* on June 5	Pre-feeding *W* on June 6
2	6	4
4	3	3
10	4	4
14	7	3
15	7	4
22	5	5
24	3.5	3.5
29	6	3
44	7	3
45	4	3
46	3	5

The result of a preference test following this amount of pre-feeding can be stated simply. *S* was eaten on every trial. There are a few sporadic records of *WS* or *wS* but there is no record of pure *W*. A more complete and convincing demonstration of *S* preference could hardly be imagined.

When *S* was pre-fed the preference was just as decisive as when *W* was pre-fed; no difference in preference depending upon pre-feeding of 100 seconds could be demonstrated.

There was, however, a difference in running activity upon the apparatus. At the end of exactly five minutes a line was drawn on the data sheet to record the number of runs made during the 5-minute period. The same was done after 10 minutes and at the completion of the 15-minute test. The number of runs in successive 5-minute periods is summarized in Table 3.

In general, there is an increase of running activity with successive

TABLE 3

NUMBER OF RUNS IN THREE SUCCESSIVE FIVE MINUTE PERIODS AFTER PRE-FEEDING SUGAR AND WHEAT

Rat	Pre-feeding *S*				Pre-feeding *W*			
	1	2	3	Sum	1	2	3	Sum
2	14	14	19	47	16	19	26	61
4	12	13	16	41	24	20	23	67
10	16	16	23	55	21	24	25	70
14	16	9	15	40	21	11	21	53
15	14	9	3	26	22	20	22	64
22	13	15	22	50	9	15	13	37
24	14	8	2	24	17	21	22	60
29	13	13	17	43	18	25	24	67
44	11	11	10	32	20	19	22	61
45	13	14	16	43	17	22	22	61
46	16	21	20	57	19	24	26	69
Total	152	143	163	458	204	220	246	670

5-minute periods, but some individuals show no such increase and Rats 15 and 24 have the reverse gradient when pre-fed *S*. For the total 15-minute period every rat but one, No. 22, made more runs when pre-fed *W* than when pre-fed *S*. Inasmuch as *S* was selected on every trial, we can assume that *S* was consistently the incentive to running. To obtain *S*, the rats were more active after they had been pre-fed *W* than after they had been pre-fed *S*.

Our conclusion is that pre-feeding *S* and *W* up to 100 eating-seconds did not disturb the consistent preference of *S* to *W*, but it did change the running activity on the apparatus, with *S* as the constant incentive. The animals were less active when pre-fed *S* than when pre-fed *W*.

Series III: *Pre-Feeding Sugar and Wheat up to 400 Eating-Seconds*

The sugar preference was so definite during the two days of Series II that instead of continuing at 100 eating-seconds to discover any ultimate change in preference with this amount of pre-feeding, we decided to pre-feed for 400 seconds.

At first we assumed that the pre-feeding of 400 eating-seconds could be accomplished within a 15-minute period. We soon found, however, that this was by no means true when *S* was pre-fed. To obtain 400 eating-seconds of *S*, some rats would have to be allowed more than 15 minutes because there was so much exploring, preening, resting, etc. We arbitrarily limited the pre-feeding time to 15

minutes whenever 400 eating-seconds could not be completed within this time.

Table 4 summarizes the total time of pre-feeding, rat by rat.

TABLE 4

NUMBER OF EATING-SECONDS AND PRE-FEEDING TIME

Rat	Pre-feeding *S* on June 7		Pre-feeding *W* on June 8		Pre-feeding *S* on June 9	
	Eating-sec.	Min.	Eating-sec.	Min.	Eating-sec.	Min.
2	280	15	400	8.5	180	15
4	400	15.5	400	9	400	15
10	400	10	400	7	400	12
14	140	15	400	7	280	15
15	365	15	400	7	245	15
22	230	15	400	10	235	15
24	340	15	400	9	400	12.5
29	360	15	400	8	390	15
44	400	15	400	7	200	15
45	400	12.5	400	7	245	15
46	400	14	400	9.5	160	15

When *W* was pre-fed on June 8 all of the animals completed the 400 eating-seconds in from 7 to 10 minutes, but when *S* was pre-fed the majority did not complete the 400 seconds within the 15 minutes allowed. On June 7 the actual range of eating-seconds was from 140 to 400; on June 9 from 160 to 400, only three rats completing the full 400 seconds of eating.

During the pre-feeding of *S* the rats stopped to explore, to preen, to remove bits of sugar from their mouths, the floor or walls of the cage, to drink, to defecate, etc. They appeared to be distractable and very unsteady in their eating. Toward the close of the pre-feeding period some rats deserted the sugar for several minutes. With *W*, by contrast, the animals attended strictly to the business of eating, and quickly and steadily completed the 400 seconds of eating.

The time data in Table 4 as well as the notes upon gross behavior might well lead one to the conclusion that *W* is preferred to *S*. How about the activity data?

The number of runs made during the daily 5-minute tests (following the pre-feeding up to 400 seconds) is shown in Table 11. The tests were limited to five minutes because it was found that with 15 minutes of pre-feeding the work could not be completed

in an afternoon unless there were some reduction in the duration of the preference test. Inasmuch as Series II had yielded consistent *S* preference, we felt reasonably sure that a 5-minute test would be ample.

In general, there were more runs on June 8 when *W* was pre-fed than on June 7 and 9 when *S* was pre-fed. The result agrees with that of Series II, Tables 3 and 11, and can be interpreted in the same way. Pre-feeding *S* reduced the running activity of the animals more than pre-feeding *W*, when *S* was the main incentive. But we cannot argue from the running activity either that *S* is preferred to *W* or that *W* is preferred to *S*.

The results of the preference test are entirely decisive. For 10 of the 11 rats consistent *S* preference was manifest on every trial of the series.

Thus the relatively weak demand for *S* indicated by running activity, by the pre-feeding times, and by gross behavior during pre-feeding, was not in agreement with the demand actually revealed by selection of food on the preference apparatus.

One rat, No. 22, behaved differently from the others and his record needs special consideration. A transcription of results for this animal during the three five-minute periods is given in Table 5.

TABLE 5

RESULTS FOR RAT 22 AFTER PRE-FEEDING OF SUGAR AND WHEAT

Trials	Pre-feeding *S* on June 7 (230 sec.)	Pre-feeding *W* on June 8 (400 sec.)	Pre-feeding *S* on June 9 (235 sec.)
1	S	S	W
2	S	S	W
3	S	S	W
4	S	S	W
5	S	W	W
6	S	S	W
7	W	S	W
8	S	S	W
9	W	W	W
10	S	S	W
11	W	S	
12		S	

The record indicates that on June 7 there were at first six univocal choices of *S*, then five indeterminate trials. On June 8 prefer-

ence was not shown by Criteria 1 and 2 but a count (Criterion 3) still shows a preference for *S*. On June 9, and incidentally on all following days of the entire experiment, this rat revealed a 100 per cent preference for *W*. The data sheets record the fact that during the transitional period this rat spent considerable time slowly smelling both foods prior to eating.

The record of No. 22 is significant as the first indication of any departure from consistent preference of *S* to *W*. The transition, it will be noted, came on gradually and steadily during these three days despite the alternate pre-feeding of *S* and *W*.

In conclusion, the writer feels that Series III is highly significant because it proves the necessity of reconsidering our initial conception of *demand*. As shown by the preference test sugar is *demanded* more than wheat throughout the series for all rats except No. 22. But the pre-feeding times, and the gross behavior of the animals during pre-feeding point to a greater demand for *W* than for *S*.

To sum up the facts: (*a*) The over-all time required for rats to eat 400 seconds of *W* was distinctly less than that required to eat 400 seconds of *S*. This result, incidentally, confirms that obtained previously with the revolving cups, which was referred to at the start of this paper. In timing the amount of continuous eating during 5, 10 or 15 minutes, *W* undoubtedly has the advantage over *S*. (*b*) Direct observation of behavior agrees with the time records. The rats ate *W* more steadily, continuously, and with less show of distractability than *S*. Some rats acted as if satiated toward the close of the pre-feeding of *S*. (*c*) Pre-feeding *S* was followed by relatively less running activity on the preference apparatus than was the pre-feeding of *W* when *S* was the main incentive. But this variation in running activity was not correlated with any appreciable change in the preference of *S* to *W*. Although one rat did change from *S* to *W* preference, the transition came on gradually despite the alternate pre-feeding of *S* and *W*.

Considering all of the above facts it is clear that *demand* as revealed by a preference test cannot be equated to *demand* as shown in gross behavior by steadiness of eating, distractability, running activity, and probably in other ways. This duality in the conception of demand is obviously in need of further investigation.

Series IV: Reversal of the Sugar-Wheat Preference through Pre-Feeding for Fifteen Minutes

In Series IV a rat was placed in the pre-feeding cage for exactly 15 minutes during which time he was given free access to an unlimited supply of sugar. Actually, the use of a 15-minute period gave about the same amount of pre-feeding as in Series III when sugar was pre-fed (see Table 4). In Series III most rats did not complete 400 eating-seconds of *S* in the 15 minutes allowed.

There were, however, two significant differences between Series III and IV. First, the observation period on the preference apparatus was limited to five minutes daily in Series III, whereas in Series IV a 15-minute test period was employed. The longer period gave the rats more opportunity to eat the test-foods.[6]

A second important difference is that in Series IV sugar was pre-fed *every day,* whereas in both Series II and III the pre-feeding of sugar and wheat were alternated. Thus in Series IV the rats had more opportunity to eat sugar than in Series III, just as in Series III they could ingest more than in Series II.

The use of a 15-minute pre-feeding period was advantageous in one respect. We planned the work so that while one animal was being tested on the preference apparatus another was in the pre-feeding box. Thus we saved our time but unfortunately could not observe eating behavior in the pre-feeding box.

We hoped to get a total of 200 trials per rat in six days. Two animals completed this number of runs in four days, two more in five, but seven did not complete the desired number of runs in six days.

The total results have been analyzed by our criteria to show preference and non-preference. They reveal a complete and spectacular reversal of the sugar preference which was so pronounced during the first part of this experiment.

Results are summarized in Table 6. The table is similar in plan to Table 2, except that it summarizes for three preferential categories instead of two—sugar preference, equality, wheat preference. The figures show the number of consecutive trials which reveal each

[6]An appreciable amount of food can be ingested on the preference apparatus, but the preference technique forces the rat to feed bite by bite and thus to extend through a period of 15 minutes an amount of eating which could be accomplished much more quickly in a feeding box. This spreading out of feeding over a considerable period of time makes it possible to observe changes in appetite which might otherwise go unnoticed.

TABLE 6

SUMMARY OF SERIES IV SHOWING TRANSITION TO WHEAT PREFERENCE

Rat	$S > W$	=	$W > S$	Comment
2		1-8	9-177	
4		1-9	10-201	
10	1-33	34-139	140-181	
14		1-6	7-115	
15	1-8	9-25	26-163	
22			1-93	Trials 1, 23, 53 S
24	1-17	18-37	38-122	
29	1-77	78-96	97-115	Trials 1, 116, 145
	116-125		126-144	are at start of
	145-172	173-210		a new day
44		1-24	25-200	
45	1-23	24-33	34-201	
46	1-9	10-31	32-225	

kind of preference and no preference. In reading the table trials for a given rat should be considered in numerical order. For example, No. 10 in Trials 1 to 33, inclusive, indicated preference of *S* to *W*, then Trials 34-139 were equivocal, finally Trials 140-181 revealed an out and out preference of *W* to *S*.

All rats manifested clear and unmistakable trends in the direction of increasing *W* preference. Four spectacularly swung over to a complete *W* preference on the first day of Series IV. Three more turned to *W* on the second. Rat 22, who had developed a *W* preference in Series III (see Table 5), maintained it consistently throughout Series IV. By the fourth day all rats revealed a complete and uniform preference of *W* to *S*. All rats, except No. 29, concluded the series with a complete and decisive *W* preference.

Rat No. 29 needs special consideration. Instead of a single, one-directional trend toward increasing demand for *W*, as found in the results for all other animals, this rat exhibited a cycle. On June 10 to 12, Trials 1 to 115, there was a one-directional trend from *S* preference, through equality to *W* preference. On June 13, Trials 116-144, there was an initial *S* preference followed by a complete transition from *S* to *W* preference; the record for this day is reproduced in Table 7 (explained below). Finally, on June 14 to 15, Trials 145-210, there was a gradual trend from *S* preference to equality of demand; the series ended before equality had developed into the expected *W* preference. Thus for rat No. 29 there were three successive waves of transition from *S* preference to *W* or in that direction.

TABLE 7

MUTATIONS OF FOOD PREFERENCE FOR TWO RATS WITHIN A FIFTEEN-MINUTE TEST PERIOD

Rat 29 on June 13			Rat 46 on June 10		
1st 5 min.	2nd 5 min.	3rd 5 min.	1st 5 min.	2nd 5 min.	3rd 5 min.
S	wsW	sW	S	S	S
S	W	sW	S	S	S
S	sW	sW	S	wsW	W
S	wsW	W	S	S	W
SW	wsW	W	S	SW	W
S	wsW	W	S	S	SW
SW	wsW	wsW	S	W	W
S	sW	W	wS	W	SW
SW	sW		S	W	W
S	sW		W	SW	W
	sW		S	sW	W
			S	SW	W
			S	W	W
			W	SW	W
			S		W

a. Transitions. The mutations of preference which we observed in Series IV are of special interest and will be considered briefly.

In the transition from *S* preference to equality of demand the most frequent event was a gradual increase of spatially determined behavior. As the series progressed a rat would eat more and more frequently the left food or that at the right regardless of quality. Some of the rats continued indefinitely eating the food in a given place with no sign of discrimination between the two test-foods. When the transition was from equality to *W* preference the reverse process took place. The spatially determined behavior gave way more or less gradually to an expression of *W* preference.

Some transitions were fairly abrupt and spectacular. Two of these are illustrated in Table 7 for rat No. 29 on June 13 and for No. 46 on June 10. The table shows the choices made by each animal during the three consecutive five-minute portions of a 15-minute test. In reading the table one should remember that a capital letter indicates an actual bite or nibble of the food while a small letter means merely tasting, i.e., contact with the tongue but not a bite. The record "*wsW*" symbolizes a touch of the tongue to wheat, followed by similar tasting of sugar, followed by a bite of wheat; the record "*SW*" means a bite of sugar followed by a bite of wheat. During the transitions there was a great deal of sniffing at the test-

foods, often very deliberate and quite obvious to the experimenter; but smelling of the food does not involve contact and hence is not indicated in Table 7.

These sequences can be described by saying that they reveal a weakening demand for *S* and a simultaneously strengthening demand for *W*. They show, in fact, a mutation of preference taking place during the 15-minute observation period.

A rare transitional pattern was presented to some extent by rats Nos. 14 and 29. The pattern for six consecutive trials was sometimes in one of these forms and sometimes in the other (read down):

SW	sW
SW	sW
SW	sW
SW	sW
SW	sW
SW	sW

We suggest that this initial eating or tasting of sugar is a hold over of the habituated sugar eating developed in Series I, II, III. The consistent turning to *W* on every trial probably indicates *W* preference; at least the pattern actually developed into consistent *W* preference. The pattern was unstable.

b. Running activity. We tabulated the number of runs made by the animals in successive five-minute periods. After studying these figures we are unable to make any statement except that they are completely lacking in uniformity. Some rats which continued to eat *S* ran less and less frequently and appeared to become completely satiated on *S*. For example, on June 11, No. 24 came slowly from the starting box to the food, smelled *S* and ran back into the box without eating; later the same day she came out, touched her tongue to *S* without eating and ran back into the box. We gained the impression that she had had enough *S*, perhaps too much.

With most of the rats there were long minutes of inactivity. Occasionally these were followed by bursts of running, the speeding up periods occurring irregularly at various times during the 15-minute period.

For the three successive five-minute periods the activity gradients were of all conceivable forms. The variability was so pronounced that we have not attempted a generalization. The reason for this

variability doubtless lies in the fact that behavior was determined by *two* incentives, effective in a varying and unknown degree, and that the organic state of the animals was variable and in transition. Under these conditions little uniformity in running activity should be expected, and little uniformity was actually found.

The total number of runs day by day is given in Table 11. The table shows an increase in running activity on the first three days of the series—the days during which *W* preference is becoming more stable. If we assume that the rats have become satiated upon *S*, it is obvious that they still have an increasing eagerness to eat *W*. The number of runs to obtain wheat in the present series, both for individuals and for the total group, is comparable to that of Series I with a sugar incentive.

In conclusion, when rats were pre-fed daily all the sugar they could eat in a 15-minute period their initial preference of sugar to wheat was completely and consistently reversed. Under conditions of the present experiment, the transition occurred gradually over a period of days, not abruptly.

During the transition we observed, (*a*) spatially-determined behavior, (*b*) alternate eating or sampling, (*c*) the temporary persistence of a habit to eat sugar.

The transition, we assume, is determined by the rats' organic state.

Series V: The Restoration of Sugar Preference by Omitting the Pre-Feeding

On five consecutive days immediately following the completion of Series IV we ran a 15-minute preference test without any pre-feeding. We had expected that the cessation of pre-feeding would quickly restore the original preference of *S* to *W*, but actually the restoration was slower and less complete than we had anticipated.

The results from Series V will be presented in four ways:

(1) Table 8, which is similar in plan to Tables 2 and 6, shows the sequences of trials revealing *W* preference, equality, *S* preference, for the five days of Series V.

Table 8 gives a clear impression of approximate equality of demand for *W* and *S*, with wide individual differences. Rat 22, the animal who in Series III first revealed *W* preference, retained that preference to the end of the experiment with no indication of a trend

TABLE 8

SUMMARY OF SERIES V SHOWING TREND TOWARD SUGAR PREFERENCE

Rat	W>S	=	S>W	Comment
2	1-8	9-61	62-67	
		68-87	88-95	
		96-115		
	116-121	122-131	132-137	
		138-176		
4		1-244		
10		1-3	4-9	
		10-36	37-122	Trials 46, 95, 113, 114 W
		123-132	133-141	
		142-156	157-166	
		167-205	206-228	Trials 213, 215, 223 W
		229-241	242-307	Trial 297 W
14		1-48	49-91	
		92-100	101-130	
		131-150	151-184	
15		1-70		
	71-78	79-81	82-184	
22	1-159			
24		1-25	26-50	
		51-60	61-91	
		92-101	102-150	
29		1-163		
44	1-50	51-122		
	123-141	142-214		
45		1-6		
	7-50	51-118		
	119-150	151-216		
46	1-13	14-252		

toward equality. Rat 46 continued to show *W* preference for 13 trials and then became indiscriminate for the rest of the series. Rats 44 and 45 alternated between *W* preference and equality throughout. Rats 4 and 29 were consistently indeterminate. Rats 10, 14, and 24 alternated between equality and *S* preference. Rats 2 and 15 presented transitions involving all three preferential categories.

When we recall that the present series follows a consistent *W* preference in Series IV, it becomes clear that the general trend is away from *W* preference toward equality and *S* preference. But the expected return to complete *S* preference is far from realized.

(2) The extent of individual differences is shown clearly in Table 9. The table summarizes the total number of runs which

TABLE 9

TOTAL RUNS FOR EACH PREFERENTIAL CATEGORY IN SERIES V

	Rat	W>S	=	S>W	Total
Wheat eaters	22	159	0	0	159
	45	76	140	0	216
	44	69	145	0	214
Indiscriminate	46	13	239	0	252
	29	0	163	0	163
	4	0	244	0	244
	2	14	142	20	176
Sugar eaters	15	8	73	103	184
	24	0	45	105	150
	14	0	77	107	184
	10	0	107	200	307
	Total	339	1375	535	2249

fall under each of the preferential categories, and consequently disregards trends.

The animals have been placed in groups: (*a*) *The wheat eaters.* Rats 22, 45, 44, did not once meet the criterion for *S* preference and all had significantly long runs of *W* preference. Possibly two of these, Nos. 45 and 44, should be placed in the next class because at the close of the series they became indiscriminate. (*b*) *The indiscriminate animals.* Rats 46, 29, 4, 2, had long runs of an indeterminate pattern with little or no manifestation of a preference for either *W* or *S*. (*c*) *The sugar eaters.* Rats 15, 24, 14, 10, had runs of more than 100 consecutive trials showing univocal preference for *S*. Three of the four did not once indicate any *W* preference, and the fourth showed *W* preference to a negligible degree.

(3) Despite the predominance of indiscriminate behavior and the wide individual differences manifest in Tables 8 and 9, there is none the less a definite trend toward increasing sugar preference which can be demonstrated in the results of the group as a whole.

The general trend can be brought out clearly by the use of Criterion 3—a count of the number of trials which are purely *S*. The manner of applying the criterion is the following.

For each rat the entire record was broken up into consecutive groups of 25 trials each. Within each group we counted the number of trials indicating unambiguous eating of *S*, and to this number we added ½ of the ambiguous trials, such as *WS* or *SW*. This count gave an index, varying from 0 to 25, which fairly represents the amount of sugar-eating in the group of 25 trials.

Next we added together these indices for the 11 rats and obtained the following group results:

Trials	1-25	26-50	51-75	76-100	101-125	126-150
S count	115	131	161	162	154	153

In interpreting the group scores one should remember that each index is based upon 275 trials (11 x 25), and that a score of 137.5 is statistically the indifference point.

Thus for the group as a whole there is a trend in the direction of increasing demand for *S*. The trend starts with a favoring of *W* and ends with a favoring of *S*.

(4) Another kind of summary is presented in Table 10, and will be discussed later.

In general, Series V presents a decided trend away from the consistent *W* preference revealed in Series IV, toward equality of demand and then an increasing demand for *S*. But the transition came with unexpected slowness and remained incomplete at the end of the experiment.

It was necessary to terminate the experiment on June 20. Otherwise we would have continued it in the expectation of restoring to all rats the initial preference of *S* to *W*. The writer believes that the original *S* preference could readily be restored. By June 20 at the close of the experiment, four rats had returned to a complete and strong *S* preference, six were indifferent, and only one persisted in *W* preference.

Survey of the Total Experiment

After the entire body of data had been scored as showing preference or non-preference we considered the record of each rat day by day. Every daily record was examined to determine whether the *majority* of trials indicated *S* preference, equality, or *W* preference. The

TABLE 10

DAY BY DAY SUMMARY OF FOOD PREFERENCES

	I No pre-feeding								II and III Pre-feeding					IV Pre-feeding (15 min.)						V No pre-feeding				
	May				June				S	W (100-400 sec.)	S	W	S	daily										
Rat	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	=	=	S	S	S	S			S	S	S	S	S	W	W	W	W	W	W	=	=	=	=	=
4	=	=	S	S	S				S	S	S	S	S	W	W	W	W			=	=	=	=	=
10	=	=	S	S	S				S	S	S	S	S	S	=	=	W	W		S	S	=	S	S
14	=	=	S	S	S				S	S	S	S	S	W	W	W	W	W	W	=	S	S	=	S
15	=	=	S	S		S	S		S	S	S	S	S	W	W	W	W	W	W	=	=	S	S	S
20	=	=	=	S	S	S	=	S																
22	=	S	S	S	S	S	S		S	S	S	=	W	W	W	W	W	W	W	W	W	W	W	W
24	=	S	S	S	S				S	S	S	S	S	S	=	W	W	W	W	=	S	S	S	S
29	=	S	S	S	S	S			S	S	S	S	S	S	S	W	W	S	=	=	=	=	=	=
44	=	=	S	S	S	S			S	S	S	S	S	=	W	W	W	W		W	=	=	=	=
45	S	=	S	S	S	S			S	S	S	S	S	S	W	W	W	W		W	=	W	=	=
46	S	S	S	S	S				S	S	S	S	S	=	W	W	W			=	=	=	=	=

TABLE 11

NUMBER OF TRIALS PER DAY*

	I				II		III			IV				V			
	May				June												
Rat	28	29	30	31	5	6	7	8	9	10	11	12	13	16	17	18	19
2	9	16	31	44	47	61	14	22	6	23	35	48	27	50	34	37	31
4	29	33	32	47	41	67	18	18	14	37	44	65	55	62	65	59	28
10	28	37	46	45	55	70	21	20	14	48	49	37	45	64	71	60	52
14	18	38	46	44	40	53	9	23	13	19	26	28	21	44	53	50	29
15	5	15	36	32	26	64	10	22	6	19	30	33	23	56	25	39	43
20	5	7	6	9													
22	6	19	32	40	50	37	11	12	10	22	28	22	6	34	31	31	29
24	17	30	41	54	24	60	8	14	14	20	17	29	23	21	39	40	34
29	17	22	21	47	43	67	11	21	13	45	40	30	29	39	39	31	31
44	9	36	43	54	32	61	16	24	18	17	36	58	70	50	54	37	41
45	6	16	37	51	43	61	17	18	13	23	33	56	52	50	57	45	27
46	34	39	42	55	57	69	15	25	13	44	45	56	70	64	52	45	48
Total	183	308	413	522	458	670	150	219	134	317	383	462	421	534	520	474	393

*In Series III, June 7, 8, 9, the observation period was limited to five minutes; for the rest of the experiment it was 15.

In Series II and III, June 5 to 9, sugar and wheat were pre-fed on alternate days in periods ranging from 100 to 400 eating-seconds. In Series IV sugar was pre-fed daily for 15 minutes. There was no pre-feeding during Series I and V.

daily ratings are summarized in Table 10. A blank space indicates that the animal did not run on the day in question.[7]

The number of runs day by day is summarized in Table 11. For comparative purposes this table has been limited to those days on which all rats completed all of the daily tests.

Tables 10 and 11 will be referred to repeatedly in the following discussion which is centered around the question: What is the effect of pre-feeding upon the preference of sugar to wheat?

E. Discussion

The picture in Series I is of the development of a remarkably uniform and consistent preference of sugar to wheat from originally indiscriminate behavior. The development is indicated both by the increasing frequency with which rats manifest *S* preference from day to day (see Table 10), and by the daily increase in the number of runs per 15-minute period to obtain *S* (Table 11). Series I is a complete confirmation of our previous experiments with the preference technique. It reënforces our contention that appetites for food are uniform, lawful, and capable of exact quantitative investigation.

Series II and III can be considered together. In these series the animals were on alternate days pre-fed sugar and wheat in periods varying from 100 to 400 eating-seconds.

This amount of pre-feeding did not disturb the initial relationship of $S > W$. The organic processes which determined the preference of *S* to *W* must be fairly constant and stable, because repeated pre-feeding within the limits of 100-400 seconds did not greatly change them.

It is true that rat No. 22 reversed his preference during Series III, but it is also true that this reversal came on gradually regardless of whether *S* or *W* was being pre-fed.

The activity record for Series II and III (see Table 11) can be interpreted directly inasmuch as sugar was selected on practically every trial. The running activity to obtain *S* is less on June 5 after

[7]Most of the blanks are explained by the fact that observations in Series I and IV were discontinued as soon as a rat had completed 200 runs, but the blank on June 1 for No. 15 is due to the escape of the animal on this day.

The total number of recorded observations in the experiment, including those not shown in Table 11 and excluding preliminary observations, is 8,139.

pre-feeding *S* than on June 6 after pre-feeding *W*; similarly it is less on June 7 and 9 after pre-feeding *S* than on June 8 after pre-feeding *W*. Obviously pre-feeding *S* reduces the animals' avidity for *S* as shown by running activity on the apparatus. Despite these daily variations in activity the preference of *S* to *W* remains constant.

It may be that these variations in the number of runs measure fine differences in the degree of demand for sugar, that they offer a more delicate measure of demand than the gross preference test which merely shows continued *S* preference throughout all these up and down variations of activity. Conceivably the degree of demand for *S* can be lowered by pre-feeding *S*, yet not enough to reverse the preference of *S* to *W*.

But it may be, as we have suggested above, that our initial conception of *demand* is in need of revision.

If we assume that the steadiness and continuity of eating indicate degree of demand, then wheat has the advantage over sugar (see Table 4 and the discussion in Series III). Possibly this impression should be explained by reference to the physical and chemical characteristics of the foods. Sugar is a more concentrated food than whole wheat; it has more calories, more energy, volume for volume.

If our reasoning is correct that the physical and chemical characteristics of a food affect the steadiness and continuity of eating, then we must abandon relative eating time as a criterion of demand, and hold to the results of a preference test. Or we may assert that *demand* is of two kinds: the demand of hunger and the demand of appetite.

The demand of hunger varies with the period of food deprivation and depends primarily upon the contractions of an empty stomach. In other experiments it has been measured by the frequency with which a hungry animal crosses a charged grill to reach food, by the time an animal will persist in digging through sand to attain the goal, by speed of learning a maze, by running activity on a food-motivation apparatus, etc. The demand of appetite, by contrast, is more stable and permanent, more dependent upon the diet and nutritive state of the animal than the demand of hunger. Appetitive demand is revealed by the quality of food selected upon the preference apparatus.

This distinction should be kept in mind in future work. In view

of the distinction we can understand the difficulty we encountered in interpreting running activity. The rat's running activity upon the apparatus varies both with hunger (as controlled by the period of food deprivation) and with appetite (as controlled by the quality of the food incentive). The demand of hunger is modified by pre-feeding and this affects running activity on the apparatus.

There are so many factors in the picture that dogmatism is not justified.

Turning now to Series IV (see Table 10), we find there unmistakable evidence for the statement that food preferences can be experimentally controlled. At the start of this experiment we had tacitly assumed that the preference of *S* to *W* could be reversed by pre-feeding *S* beyond a certain critical time *on any given day;* but actually the reversal came about gradually over a period of several days. Possibly if we had used longer pre-feeding periods—one to six hours—the reversal would have occurred on a single day. The experiment should be tried.

The reader will recall that prior to Series IV the rats had been pre-fed sugar on alternate days. I suspect that all or most of the rats were on the point of turning to wheat before Series IV commenced, and the change to *daily* instead of alternate-day pre-feedings of *S* was just enough to push them over the line. The first day of Series IV gave two consecutive days of pre-feeding *S* for the first time in the experiment.

Throughout Series II, III, IV, the quantities of sugar consumed by the rats were gradually increasing, and beyond a certain point the preference reversed. When the reversal of sugar-wheat preference came, the perference for *W* was just as complete, uniform, and certain as the original preference for *S* had been in Series I.

At the start we tacitly assumed that the omission of pre-feeding would at once restore the original preference. Instead of this there was an unexpected slowness and gradualness of return toward sugar preference.

Series V gives a picture of equality in appetitive demand for the foods, with marked individual differences among the rats in preference, and with an unmistakable trend toward increasing preference for sugar. We note, however, that No. 29 (see Table 10) turned away from *W* while we were still pre-feeding *S*. This incidental result should make us cautious in interpretation. Possibly if we had used a longer pre-feeding period, No. 29 would have stayed with

wheat. Possibly this marked the beginning of a general reaction against *W* which would have occurred with continued pre-feeding of fifteen minutes daily. The meaning of this premature turning to *S* is not clear.

The gradualness of the return to sugar in Series V must be explained by reference to the animals' organic state. The process of building up and tearing down glycogen goes on daily and hourly as long as we live. The amount in the liver is changing all the time. Because the amount of glycogen stored in the rats' bodies became excessive it took several days to reduce it. This, we believe, is why the return toward sugar preference was so slow. Had we stopped pre-feeding sugar just as soon as wheat preference appeared, the original sugar preference could probably have been restored in a day or so.

Assuming that the nutritive state of the animal regulates appetitive demand, the essential control is over the diet. The results of Series V indicate that *post*-feeding would change the organic state and the preferences as truly as *pre*-feeding. The comparison of *post*-feeding and *pre*-feeding becomes an experimental problem.

1. *Some Questions*

The fact that the preference of sugar to wheat can be reversed implies that the organic conditions which regulate the appetitive demand for sugar and for wheat are, at least to some extent, functionally independent. If there were a single hunger factor, satiation upon sugar would bring also satiation for wheat; but this was not the case. When a rat has been fed upon sugar until he rejects that food he will still run actively to obtain wheat (see Table 11, Series IV).

Reversal of the sugar-wheat preference is only one instance among others which we have found in our various preference studies. We previously reported the reversal of preference between butter-fat and wheat (1), and a similar reversal is implied in the comparison of dry whole milk (klim) and wheat, by the revolving-cup technique (4).

These questions arise: What foods or groups of foods vary independently in relative demand? Can *any* preference which has been demonstrated between two foods be reversed, or is reversal possible only between *certain* pairs of foods? If the latter, what pairs can be reversed and what cannot? Does the reversal of preference between

a pair of foods leave other preferences unchanged, or does it change them, and if so, how?

Fundamental problems relate to the organic states which determine food preferences. By what bodily processes or mechanisms are bodily needs asserted in behavior? What bodily needs do and what do not manifest themselves in the selection of foods? To what extent can an animal select a food (3) which is adequate to its nutritional need?

Problems relating to the learning to like and dislike foods are of psychological importance.

In a significant experiment, Harris and collaborators[8] have shown that rats with a vitamin *B* deficiency select foods containing this vitamin in preference to those which lack it. If rats do not at once select the vitamin-adequate diet from a large number of others, they can be "educated," i.e., fed the adequate diet for a few days until they have experienced its beneficial effect. Thereafter the vitamin-depleted rats will continue eating the adequate diet notwithstanding its monotony. The vitamin can be placed in almost any diet of the group and the rats "educated" to eat this diet. Thus one group of rats may be trained to select a cocoa-plus-vitamin diet and another bovril. Harris and collaborators believe it is the association between the distinctive character of a diet—smell, taste, appearance—and the experience of prompt beneficial effects which is significant in determining preference.

It seems to the present writer that the essential problem raised by this work is the nature of this "education" or learning. How far is it a neural process and how far is the adjustment a chemical one? Underlying the learning process is always the organic state which directs and energizes behavior.

Assuming that our rats *learned* to select sugar instead of wheat, we must still turn to the organic state to find out why they turned to sugar rather than wheat, and why after they had been pre-fed sugar they "learned" to select wheat.

Light can be shed on many of these questions through careful research with the preference technique combined with adequate control of the diet.

---

[8]L. J. Harris, J. Clay, F. J. Hargreaves, and A. Ward. Appetite and choice of diet. The ability of the vitamin *B* deficient rat to discriminate between diets containing and lacking the vitamin. *Proc. Royal Soc.*, **1933**, **113**, 161-190.

F. Summary

In agreement with previous experiments, the results of a preference test using a group of 12 rats revealed a consistent and uniform preference of sugar to wheat.

After this the animals were pre-fed sugar and wheat on alternate days for 100 to 400 eating-seconds, just before they were given the preference tests. Five days of this did not disturb the initial sugar preference, except for one rat. But when pre-fed daily for 15 minutes all the sugar they would eat, the rats completely reversed their original preference. This transition came on gradually and not to all the rats at once, but the reversal was definite and decisive. By the fourth day all the rats preferred wheat instead of sugar.

When pre-feeding of sugar was discontinued the rats did not at once return to their initial sugar preference. Much indiscriminate behavior and wide individual differences were revealed. There was, however, a gradual but unmistakable trend first toward equality, and then toward increasing demand for sugar. After five days without any pre-feeding, when the experiment was discontinued, four out of eleven rats had returned to a definite and consistent sugar preference, six were indiscriminate, and one still held consistently to wheat preference. This study leaves no doubt that the preference between two foods can be experimentally reversed through the control of pre-feeding.

Incidental findings are these: (*a*) When rats are pre-fed sugar the running activity on the preference apparatus is less than when wheat is pre-fed, provided sugar is the preferred food. Despite these variations in running activity, the preference of sugar to wheat remains constant. (*b*) During pre-feeding, rats eat wheat more steadily than sugar, and with less distractability. They complete 400 eating-seconds of wheat in a considerably shorter period than they do of sugar. This is possibly due to differences in the physical and chemical characteristics of the two foods (sugar being a more concentrated food than whole wheat).

If we depend upon relative eating time, steadiness of eating, distractability of behavior, as criteria of demand, wheat has the advantage over sugar. But this conclusion is contradicted by the direct preference tests. Further, if we depend upon running activity as a criterion of demand, we are confronted with the fact that running

activity may vary within a considerable range while food preference is qualitatively constant. Such discrepancies force us to re-consider what we mean by food-demand and what are its valid criteria.

References

1. Young, P. T. Relative food preferences of the white rat: I. *J. Comp. Psychol.*, 1932, **14**, 297-319.
2. ———. Motivation of Behavior. New York: Wiley, 1936. (Pp. 91-93).
3. ———. Relative food preferences of the white rat: II. *J. Comp. Psychol.*, 1933, **15**, 149-165.
4. ———. Preferences and demands of the white rat for food. *J. Comp. Psychol.*, 1938, **26**, 545-588.

Department of Psychology
University of Illinois
Urbana, Illinois