

FOOD-SEEKING DRIVE, AFFECTIVE PROCESS, AND LEARNING

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The purpose of the present paper is to consider some of the theoretical implications of the writer's experiments upon food acceptance (21, 22, 23, 24, 25, 26, 28, 29, 30, 31, 32, 33, 34, 35, 37, 38, 39) and the relation of these experiments to current views concerning drive, affective process, and learning. If the reader wishes to study the background literature, much of which is taken for granted here, he is referred to the bibliographies of published critical reviews (27, 36).

THE WRITER'S EXPERIMENTS UPON FOOD ACCEPTANCE

The writer's first observations upon food preference were made in Berlin in 1927 in an attempt to escape the limitations of a purely introspective study of the affective processes (21). At that time it was our hope to find a sound objective basis for the analysis of affectivity and eventually to discover in brain dynamics the physiological equivalent of pleasantness and unpleasantness. A sound objective basis for affective psychology has been revealed by the work of many investigators, but the brain dynamics of affective arousal remain as a puzzle.

Our second group of experiments upon food preference (22, 23, 24) confirmed the findings of the first work. In general, we found a remarkable uniformity and stability in the preferential selections of rats when the animals are maintained upon a constant diet. Test-foods arrange themselves into transitive series, or hierarchies, symbolized as follows: $A > B > C > D > E > F$. A given preference may not be apparent

at the start of a test but with continued testing a preferential trend appears. Rats *learn* to make preferential discriminations.

Hierarchies of preferences are remarkably stable. The percentage of choices which indicates a preference increases with practice in discrimination. This percentage decreases during sickness and under extreme deprivation (33). It varies somewhat with the form of apparatus employed in testing (31). But despite these variations in the percentage of choices showing a preference, the hierarchy of preferences itself remains surprisingly constant.

We first found evidence that the hierarchy of food preferences can be altered experimentally in work upon the reversal of preferences through controlled pre-feeding (26). This experiment showed clearly that a given preference, $A > B$, can be reversed by permitting rats to ingest A for a controlled period of time prior to tests of preference. The change from $A > B$ to $B > A$ did not come at once; it came gradually with practice. When pre-feeding was discontinued there was not an immediate return to the original preference but only a gradual preferential trend in that direction. If food preferences are determined solely by internal chemical conditions, we argued, these reversals of preference should occur immediately. The fact that several days of training were required to change a preference indicates that rats have to *learn* to make preferential discriminations. But the *kind* of preference which the animals consistently learn, whether $A > B$

or $B > A$, is dependent upon intra-organic conditions rather than practice.

A further investigation confirmed the fact that the percentage of preference depends upon practice as well as upon the intra-organic chemical state (28). All of the early work, in fact, emphasized two interdependent conditions of food preference—(a) practice and (b) the chemical state of the organism as regulated through the diet.

A major advance came with the introduction of self-selection maintenance and the exact chemical control of the diet (29). These changes in the conditions of maintenance were made in the hope of discovering the relation between our earlier findings and the results obtained by Richter (27).

In the first major experiment combining self-selection maintenance with preference testing, Young and Chaplin (37) found a surprising result. An attempt was made to reverse a preference $A > B$, by creating a need for B through dietary deprivation. It was found that despite prolonged deprivation of B, and with marked signs of bodily need for B, the rats continued to accept A in preference to B. A new technique of testing preference was then tried. With the new technique the reverse preference, $B > A$, at once developed! For a few days the rats exhibited simultaneously two opposed preferences! When placed in the apparatus with which they had first been trained (test-foods side by side and relative positions interchanged from trial to trial) the rats preferred A to B; but when placed in a new apparatus (test-foods widely separated as in a Y-maze and relative positions fixed throughout the test) they preferred B to A. Here was an obvious exception to the rule that test-foods arrange themselves into a transitive series! Here also was a problem for any one who maintains that rats select foods in accordance with bodily

needs, since one choice agreed with bodily needs and the other did not!

The interpretation of the Young-Chaplin result became a matter of critical importance for the theory of food acceptance. Our first explanation of the result was that there are two kinds of food preference: one based upon palatability and determined by the head receptors ($A > B$) and the other based upon organic need and dependent upon chemical conditions within the organism ($B > A$). We assumed that a choice necessarily made on the sole basis of the head receptors might differ from one made when the head receptors could not function as determiners of choice (by having the test-foods out of range of the head receptors at the point of choice). This explanation of the two simultaneous preferences, however, was necessarily abandoned after a tedious series of control experiments. The validity of a distinction between palatability and appetite has been demonstrated in more recent experiments, but the distinction was not validly demonstrated by the work of Young and Chaplin.

Control experiments proved conclusively that the Young-Chaplin result did not depend upon the method of testing (31). When the amount and distribution of practice was controlled and the diet held constant the two methods of testing (foods-together and foods-apart) yielded precisely the same kind of food preference, although the degree to which a preference was revealed (as shown by the percentage of preference) varied somewhat with the kind of apparatus employed. Despite several attempts, we were unable to demonstrate one preference with one kind of apparatus and the opposite preference with another *when the factor of practice was held constant*. Returning to the Young-Chaplin result, then, we were forced to the conclusion that one kind of prefer-

ence, $A > B$, revealed a persistent preferential habit based upon the *original* relationships of palatability and that the other kind of preference, $B > A$, rested upon some factor or factors other than habit. Inasmuch as the newly forming preferential habit agreed completely with known and manifest bodily need, in this and in a similar experiment upon hunger and thirst (30), we concluded that *preferential feeding habits tend to form in agreement with bodily needs, but established feeding habits may persist regardless of bodily needs*. A preferential feeding habit, in fact, may obscure some existing need.

The final interpretation of the Young-Chaplin result confirmed the view that feeding habits alone may determine the preferential selection of food. Importantly, however, the chemical condition of the organism as determined by the diet, regulates the initial choice.

Our research bifurcated at this point. One line of investigation was directed toward the analysis of habit as a determiner of choice (32, 33, 34). The other line of work was turned toward the chemical and intra-organic factors (other than habit) which regulate the selection of food (35, 38).

Experiments upon the habit factor have culminated in the finding that the rate of learning is not dependent upon the palatability of the food which is used as an incentive (33, 34). We have found no evidence for the view that rats *learn faster* when offered a highly palatable food than when offered a food of low palatability, *provided the frequency and distribution of nibbles of food are the same for the two incentives*. At all stages of practice, however, rats *run faster* to reach a highly palatable food than to reach one of low palatability. Further, there is less day-to-day variance with the more palatable food. Also rats delay less in the presence of the highly palatable food before ac-

cepting it. If one thinks in terms of the total performance, there is no doubt that the level of performance is higher with a highly palatable reward (sugar) than with one which is less palatable (casein) *at all levels of practice*.

The second line of investigation has been concerned with determinants of food acceptance other than practice, or training. This work has shown the necessity of distinguishing between intra-organic and environmental determinants of food acceptance (35, 38). The selection of food by the rat clearly depends upon the characteristics of the foodstuff. For example, if solutions of sodium chloride are presented under stable conditions of maintenance, the animals show a marked preference for solutions with a concentration of approximately 0.7 per cent. This optimal concentration is not significantly altered by the dietary deprivation of sodium chloride nor even by surgical removal of the adrenal glands.

The evidence which is now at hand leaves little doubt that the level of acceptability depends directly upon characteristics of the food object—its kind, the concentration of solution, its temperature, texture, etc. The term *palatability* is commonly used within the science of nutrition to refer to the fact that the relative acceptance of food is dependent upon the characteristics of the foodstuff. This concept is even more important in psychological analysis than in nutritional investigations.

When the organic state (and hence appetite) is held constant and when the factor of habit is controlled, the selection of food still varies markedly with the properties of the foodstuff (palatability). Hence instead of the two factors which our early work disclosed (habit and biochemical state of the organism) we must henceforth reckon with three: (a) habit and (b) the

chemical state of the organism and (c) the characteristics of the foodstuff.

The present analysis is based mainly upon our experimental findings. The aim of this study is to find how our results relate to fundamental concepts of motivation, affectivity, and learning. Although the laboratory findings can definitely be stated in terms which are free from hypothesis, the findings are here used as a springboard for interpretation and theory.

DO ANIMALS SELECT FOODS WHICH THEY NEED OR FOODS WHICH THEY LIKE?

Bodily need is an objective nutritional concept which can be defined without reference to behavior. Need is shown by certain symptoms of depletion such as retardation of growth, failure to reproduce, loss of hair, softening of the bones, failure to maintain a homeostasis, or by death itself. Operationally, *need* can be defined in terms of specific or general dietary deprivations and the associated symptoms or syndromes which appear after specific periods of partial or total deprivation. There are, of course, psychological manifestations of need as well as structural changes: increase or decrease in the average level of food intake, increase or decrease in the level of activity, defective vision, retardation in performance upon the maze, changes in food preferences, etc. These and other manifestations of need have been studied by psychologists. Further references to the behavioral manifestations of need are frequently met in the nutritional literature.

Some psychologists have used the term *need* as practically synonymous with *drive* or *motivation*. This usage is misleading since a *drive*, in the psychological sense, is something very different from the dietary requirements as specified by a nutritionist.

Richter (15, 16) has argued that the maintaining of homeostasis is a fundamental process and that self-regulation includes the mechanisms of behavior. When there is need for a specific substance in order to maintain homeostasis the rat becomes sensitized to the substance required. The animal is able to select and balance his diet according to bodily needs and his food selections are, to a considerable extent, a dependable index of those needs.

Our work supports Richter's contention that to a considerable extent food selection is an index of bodily need. We have found, for example, that a food preference can be reversed either by satiating a rat upon the preferred food or by depriving him of the non-preferred food. Satiation, presumably, removes a need by reducing it to zero, thus meeting it completely. Deprivation of some substance which is essential for growth or reproduction or health or for survival itself builds up a bodily need for that substance. Thus food preferences change in agreement with bodily needs.

There are, however, a good many impressive facts which indicate that food selection is *not* a dependable guide to the existence of bodily needs and that factors other than need are important determinants of food acceptance. Some of the facts which present difficulties to the theory that food selections reveal needs are summarized in the following generalizations:

1. Marked food preferences develop when there is no known metabolic need and when growth and health are normal. If rats are maintained upon a fully adequate diet, with an unlimited supply of solid food and water in their cages at all times, they still reveal marked food preferences among test-foods which are supplementary to the main diet (34). Where no known metabolic need exists one can hardly

appeal to some need in explanation of the facts.

2. Rats accept with avidity a substance which meets no metabolic need. Hausmann (10), Beebe-Center, *et al.* (3) have shown that rats prefer water sweetened with saccharin to plain water. Saccharin, as we know, has no value in nutrition; it passes through the body unaltered and it could not possibly meet a metabolic need. A direct explanation of the facts in terms of bodily need would be superfluous and misleading.

3. The quantity of a particular foodstuff ingested varies markedly with its characteristics such as temperature, concentration of solution, texture, and the like, as well as with the surroundings of the foodstuff which are not directly related to intrinsic properties. If bodily need alone determined food acceptance, one would expect to find fairly constant quantities of a substance ingested per day per animal. But when solutions of sucrose or of sodium chloride are presented in different concentrations, the daily intake of these substances and of the total solution varies markedly with the concentration (35). In fact, we can regulate the intake of certain substances, to some extent, by varying the concentration.

4. If foodstuffs are presented under optimal conditions, an animal may eat to excess. Nelson (13) has reported that when rats can obtain sodium chloride at a concentration of 0.8 per cent (which is very near our observed optimal concentration) they ingest great quantities of it. Under these conditions their growth is retarded, their kidneys and other organs become enlarged, and there are doubtless other symptoms of an excessive intake of sodium chloride. In other words, rats may take much more of a food than the quantity required to maintain homeostasis when the food is obtainable under optimal

conditions. It may prove possible, when palatability is adequately controlled, to study diseases of excess as we now study deficiency conditions.

5. Rats sometimes fail to select foods in agreement with known bodily needs. For example, when deprived of vitamin D, rachitic rats failed to show a preference for a food containing the vitamin over a food which lacked the vitamin (20, 39). Other experiments have given this same result. Further, individual animals differ in their ability to select foods wisely.

6. Toxic substances are occasionally accepted by animals and men with fatal result. For example, acetate of lead (which is deadly poison) is sweet and definitely acceptable. With other poisons it may be that there is no flavor to the toxic substance or that the flavor of a small but lethal quantity is masked by the flavor of other substances. In any event, it would be difficult to explain the facts of poisoning and of allergy in terms of a need-acceptance theory.

7. Animals and children, even adults, may refuse a medicine which has a foul odor despite the fact that the medicine is known to be curative. This normal behavior places palatability above the requirements of health. The question of bodily need may not enter the picture. Again, people accept and even enjoy foods for which they have an allergy or which subsequently produce ill effects.

8. Feeding habits may regulate the selection of foodstuffs with little regard to bodily needs. A rat may persistently take the food presented in a fixed position or in a favored container regardless of its quality. Such indiscriminate feeding can have no possible relation to nutritional need. Moreover, an established habit of feeding may lead to selection of food which is di-

rectly opposed to known bodily need (33).

Now a candid study of the above facts will convince the impartial reader that the meeting of bodily need is one thing and food acceptance something else. Although food selections often are in accord with nutritional needs, the correlation between need and acceptance is far from perfect. Food acceptance is regulated by the characteristics of the food object (palatability), by the environmental surroundings of the food object, by established feeding habits, as well as by intra-organic chemical conditions which themselves may or may not be directly related to metabolic needs.

In the present paper the writer is basing a theory of food acceptance upon the assumption that contact between head receptors and a food object produces an immediate affective arousal. When a rat tastes and touches and smells a food there is an immediate liking or disliking, an enjoyment or disgust, with a certain degree of affective intensity. To put the matter bluntly: our work leads to the view that rats accept foods which they *like* (find enjoyable) and that foods differ in the degree to which they arouse immediate enjoyment. A preferred food is more intensely enjoyed than one which is not preferred.

This view, that the selection of food-stuffs is determined by the degree of enjoyment, is obviously different from the view that animals accept foods which they *need* to maintain homeostasis and to survive. The two interpretations, however, are not logically opposed, and they may be regarded as supplementary.

Fortunately, the relation between nutritional need and affective arousal can be explored experimentally. Available results show that to an appreciable extent rats *like* foods which they *need*.

In general, foods which are required to maintain homeostasis or to cure deficiency symptoms 'taste good' to the animal. The question should be asked: To what extent do animals accept foods which the nutritionist tells us they need? And what bodily mechanism regulates food acceptance in such a manner that bodily needs tend to be met?

There are other more fundamental questions which are easier to ask than to answer: How can affective arousal be described in terms of brain dynamics and in terms of biochemistry? How are the affective processes related to the formation of specific food-seeking and food-selecting drives? How are affective processes related to the organization of purposive behavior and to learning? Some of these questions will be considered below.

FOOD-SEEKING DRIVES AND AFFECTIVE AROUSAL

General hunger. The prevailing theory of general hunger may be called the *need-stimulus* theory. According to the need-stimulus theory, general hunger is a condition of need produced by the privation of food. The mechanism of the general hunger drive is usually pictured in terms of the contractions of an empty stomach. The empty stomach contracts, thus stimulating nerves within its muscular wall. The frequency and persistence of gastric hunger contractions increase as the general need for food increases. Stimulations from these contractions excite the organism, raising the level of general activity; they also underlie the subjective hunger pang. The condition of hunger is normally relieved by ingestion of food which puts an end to gastric hunger contractions and meets the bodily need for food.

Through a process of conditioning, according to the prevailing theory,

food-seeking behavior becomes increasingly controlled by environmental factors. The usual view is that acts which meet the bodily need and reduce the hunger contractions are 'reinforced.' Primary 'reinforcement' comes from the meeting of a primary bodily need such as the need for food. 'Secondary reinforcement' comes from stimulus-patterns more or less directly associated with the reduction of a primary need. Thus the visual and auditory stimulations from laboratory gadgets which deliver food are said to furnish 'secondary reinforcement.' Through 'secondary reinforcement' the rat learns to run a maze, to make a visual discrimination, to press a bar, to dig through sand, to endure an electric shock, to run on a preference apparatus in order to reach and ingest food.

This development of an increasing environmental control over feeding behavior has been aptly called the *externalization* of drive (1). The doctrine of externalization implies the existence of an original internal drive. The hypothesis of externalization becomes unnecessary, however, if we recognize that all food-seeking drives are learned on the basis of an immediate enjoyment of food.

Internal hunger, of course, does exist. The hungry infant does cry and scream and kick. The nipple in the mouth does bring quiescence. No one wants to close his eyes to any important group of facts.

But the prevailing theory of general hunger drive is inadequate. It has been criticized on a number of counts which will not be reviewed here. We will point out only that this theory has no explanation to offer for specific hungers. Nor does it have an explanation for the facts of food preference.

Specific hungers. The argument for the existence of specific hungers, or ap-

petites, rests upon 'independent variability' in the intake of foodstuffs. In the laboratory the average daily intake of one substance—protein, fat, carbohydrate, water, sodium, phosphorus, calcium, riboflavin, etc.—is found, under certain conditions, to vary independently of the intake of the others.

Independent variability in the intake of foodstuffs can be demonstrated by surgical operation. Removal of the adrenal glands, for example, increases the intake of sodium. Removal of the parathyroids increases the intake of calcium. Changes of relative intake occur during pregnancy and lactation. There are changes with age. And the removal of one substance from the diet is often associated with compensatory changes in the intake of other substances. The interrelationships, as we know them, are complex.

Independent variability in the intake of separate foodstuffs can be shown by experiments upon partial satiation. We have shown that a food preference can be reversed by satiating a rat upon the preferred food. When satiated upon one kind of food, however, the animal continues to accept other kinds of food. An instance of partial satiation is found in some observations which were reported by Bousfield (5) upon the feeding of cats. He reported that when cats are fed to satiation upon one kind of food they continue eating other foods and yield further curves of approach to satiation. Thus by measuring the quantities of food ingested Bousfield was able to demonstrate and determine the extent to which eating one kind of food reduced the strength of drive to eat another.

Independent variability of appetites in the selection of foods has been demonstrated clearly by Richter's method of self-selection feeding. The strength of this method lies in the fact that it presents to the animal a constant and

controlled nutritive environment. The method makes it possible to observe changes of intake for a group of substances and to study the conditions upon which such changes depend. With this method Richter has demonstrated independently varying appetites, or specific hungers.

One difficulty with Richter's method, as used thus far, is that a clear distinction has not been drawn between appetite and palatability or, more simply, between the intraorganic and the environmental determinants of food acceptance. To illustrate this difficulty let us consider Richter's technique for determining the preferential taste threshold. In these threshold determinations the main variable is the concentration of solution. If the organic state is held constant, the preference between distilled water and solutions of sodium chloride is found to vary with the concentration of solution. Since these differences depend upon the characteristics of the food object, one can argue that they are differences in *palatability* rather than differences in organic *appetite*.

The distinction is more basic than the words suggest. Studies of food preference reveal the existence of preferences with almost any pair of test-foods picked at random. The preference tests yield plenty of evidence for independent variability in food selection. But shall we assume from this fact that every pair of test-foods yields evidence for the existence of independently variable *appetites*? Hardly, because in that event we would have to assume almost as many specific appetites as there are different kinds of foodstuff.

The writer believes that to make the concept of appetite, or specific hunger, precise there must be added to the requirement of independent variability one further requirement: *the independent variability in food acceptance must*

be shown to depend upon intra-organic chemical conditions and not merely upon the characteristics of the food-stuff as such. To demonstrate separate appetites, or specific hungers, therefore, one must show independent variability in intake which depends upon intra-organic conditions.

From this point of view Richter's demonstration that the preferential salt threshold is lowered by adrenalectomy is a fact of great importance for the theory of appetite because adrenalectomy does constitute a change of intra-organic conditions.

At the present time the bodily mechanism which regulates selective food acceptance is not known. Richter has assumed that animals become sensitized to substances which are required to maintain homeostasis and hence for existence. This mechanism, if it exists, is one of obvious biological utility. If an animal needed sodium, for example, the preferential threshold for this substance would be lowered.

In a study of the threshold for sodium chloride, Bare (2) confirmed Richter's finding that the preferential threshold is lowered by adrenalectomy, but he drew an important distinction between the *absolute sensory threshold* and the *preferential threshold*. Adrenalectomy lowered the preferential threshold, but it did not change the absolute sensory threshold for sodium chloride as determined by electrophysiological methods. In other words, the difference between normal and adrenalectomized rats is not one of gustatory sensitivity but rather one of preference. This finding again raises the question of the nature of preference and the bodily mechanisms of preferential food selection.

Young (31) pointed out that selecting and balancing a diet according to bodily needs can be explained by a mechanism of selective satiation as

readily as by the lowering of gustatory thresholds. When an animal steadily eats a specific kind of food, the responsiveness of the gustatory cells decreases, we may assume, until at satiation the responsiveness becomes zero. In this connection, it should be pointed out, Richter's method of continuous exposure permits a rat to ingest a food up to the limit of satiation and to keep himself satiated throughout the 24-hour period. It may very well be, of course, that satiation has nothing to do with the gustatory cells as such but that it is a more general physiological phenomenon.

The discovery of the bodily mechanisms of specific hungers, or selective appetites, will have to await the accumulation of further facts. It is our contention that the essential facts must be found within the science of behavior. Accepting one food, rejecting another, accepting with more or less avidity, preferring one food to another, running or working or accepting pain to obtain food, learning to operate the innumerable laboratory gadgets which lead to food—what are these other than *behavioral* facts? Physiologists and nutritionists have not been very enlightening in the matter of specific hunger, palatability, and feeding habit. This is probably because they have lacked the benefit of sound behavioral fact and psychological principle.

The basis of food-seeking and food-selecting behavior. The terms *specific hunger* and *appetite* suggest more than a state of bodily need. They suggest a desire or specific craving which has its basis within the tissues. They suggest that within the organism there are mechanisms which determine the seeking and selecting of foods. What is the nature of the physiological mechanisms which regulate selective food acceptance?

Before attempting to answer the question let us examine a bit of experimental evidence (34):

A rat is placed in the starting-box of our preference apparatus. After 60 seconds the door is opened and the animal is free to move forward upon an open field to sugar or casein exposed in a glass tube 38 cm. in front of the door. After a nibble the food is lowered out of reach. The rat now explores the apparatus and sooner or later returns to the starting-box from which he is removed. The experimenter has measured with a stopwatch the time between release from the starting-box and initial contact with food. In the experiment under consideration there are two groups of rats. The animals in one group are rewarded on each daily run with a nibble of sugar; those in the other group, with casein. At the start all rats spend considerable time exploring the apparatus and some of them seem to find the food quite accidentally. With practice the animals run more and more directly to the food. Occasionally a practiced rat may be seen poised at the door of the starting-box and oriented toward the food (especially with sugar). After a few days of practice there is this difference between the two groups. The animals running to sugar accept this food almost at once; they do not pause to explore until after the food has been lowered out of reach. Their speed of locomotion in approaching the sugar steadily increases from day to day and their day-to-day variance of performance is relatively low. In contrast, the rats running to casein are slower; they delay longer before accepting the food and sometimes pause to explore before accepting it. Their performance shows less change with practice and the day-to-day variance of performance is definitely greater than that of the sugar-incentive rats. Since all experimental conditions are the same for the two

groups, except the kind of food, we may conclude that observed differences in behavior are dependent upon the kind of food offered as a reward or incentive.

The observed difference between running-to-sugar and running-to-casein can accurately be described as a difference in the strength of *behavioral* drive. This difference cannot be explained by reference to metabolic needs since in this particular experiment all rats were well nourished, free from any known metabolic need, and free from general hunger throughout the experiment. The behavioral difference between running-to-sugar and running-to-casein cannot be attributed to practice, since the frequency and distribution of runs were the same for both groups. At all stages of practice the food-approach time was less for sugar-incentive rats than for casein-incentive animals. The difference in behavior between running-to-sugar and running-to-casein cannot be referred directly to gustatory stimulation since the test-foods were out of the range of head receptors during most of the run and since, with only one run per day, there was an intervening period of 24 hours between successive gustatory stimulations. Upon what does the difference in food-seeking behavior depend?

The most probable answer is that with practice the animals developed a neuromuscular set which directed them to the food in the center of the apparatus. This set maintained a persistent orientation toward the goal and its tension component was responsible for release of energy in food-seeking behavior.

We assume that when a practiced rat is placed on the apparatus there is reintegrated a preparatory set. Along with this there is a proprioceptive tension associated with the preparation to run to food. The proprioceptive tension, implying changes in muscle tonus, is a persistent motivation within the

food-oriented rat. Persistent drive-stimulation comes from the muscles, tendons, and perhaps the joints, when a specific food-seeking determination has been activated by the environmental situation. This proprioceptive tension, we assume, is greater in the running-to-sugar drive than in the running-to-casein drive.

When the animal is removed from the apparatus this proprioceptive tension relaxes. Then all that is left of the neuromuscular set is a learned neural organization which remains as a potential basis for reintegrating the set when the rat is again placed in the starting-box. The neural organization, we assume, may persist indefinitely apart from tonic changes in the muscles and independently of the chemical conditions within the body which regulate the relationships of palatability. The acquired neural organization holds over from day to day as the animal gradually learns to run to a particular food.

In the experiment under consideration tests of preference showed that rats prefer sugar to casein. When given repeated choices between these foods they accepted sugar with increasing frequency and casein with decreasing frequency. The acquired running-to-sugar drive acted as a selective factor in the situation.

The behavioral running-to-sugar drive is definitely and consistently stronger than the running-to-casein drive at all levels of practice. Our criteria for determining the strength of drive are: the speed of locomotion, the latency of food acceptance, and the results of direct tests of preference. We would predict that other measures of the strength of drive (of which there are a good many) would give the same result in the comparison of these two food-seeking drives.

If we could fathom the conscious experiences of the rat, we would probably detect a difference between running-to-

sugar and running-to-casein. Certainly a man recognizes a qualitative difference between the expectancy of one kind of food and the expectancy of another kind of food. Moreover, the behavior of the rats suggests that they *like* sugar better than casein, that sugar is more enjoyable than casein. Insofar as rats resemble men, qualitative differences in expectancy and in enjoyment exist.

But apart from speculation there can be no doubt that quantitative differences do exist in the strength of the behavioral food-seeking drives, which differences are dependent upon the *kind* of food, and that the strength of drive is directly related to the palatability level of the foodstuffs.

Affective processes and food-seeking determinations. Our interpretation of the facts is that when the head receptors make contact with a specific food there is an immediate enjoyment with a definite intensity of affective arousal. The behavior of the total organism acts to continue and preserve this enjoyment. It is to preserve enjoyment that neuromuscular determinations are organized. Moreover, the intensity of enjoyment is correlated with the strength of determination to continue and preserve it. For example, the determination to continue eating sugar is stronger than the determination to continue eating casein.

We will tentatively call this view the *affective-determination* theory to have a designation which stands in contrast with the prevailing *need-stimulus* theory of drive. According to the affective-determination theory all specific food-seeking and food-selecting drives are learned. They are organized cortically to continue and preserve an immediate enjoyment of foods which in some degree are acceptable.

According to the need-stimulus theory 'primary reinforcement' comes from

the relief of need. According to the affective-determination theory the relief from distress in any form is an affective change. The organism organizes central determinations which continue those behavioral patterns which lead to the relief of distress. Food-accepting behavior may be organized on the affective basis of relief from organic hunger (as postulated in the need-stimulus theory) but actually the experimental facts point more clearly in a different direction. It is an immediate positive affective arousal (enjoyment of food) which leads to the organization of food-seeking determinations rather than the more remote and delayed relief of gastric hunger. Food deprivation operates in some way to make the foods of which the animal is deprived more enjoyable when contact with them has been made.

According to the need-stimulus theory 'secondary reinforcement' comes from the activities of chewing and swallowing food and from the environmental stimulations which immediately precede these activities. These activities become 'reinforcing' because they are associated with the reduction of gastric hunger. According to the affective-determination theory it is the immediate and direct contact of head receptors with foodstuff which produces an affective arousal and on the basis of this affective arousal a food-seeking determination is organized.

Food-seeking drives and food selection may also be based upon the relief from internal distress, especially from the symptoms produced by deprivation of a needed substance. In a pioneer study of the appetite for vitamin B, Harris *et al.* (9) have shown that the rat must *learn* to associate relief from deficiency symptoms with some characteristic of the food before the appetite for the vitamin can be demonstrated. More recently, Scott and Verney (17)

have confirmed this view. They concluded that the appetites for thiamine, riboflavin, and pyridoxine are acquired on the basis of a subjective feeling of well-being which is associated with some characteristic of the vitamin-containing food. Again, after an extended series of experiments with chemically pure foods, Scott and Verney (18) concluded (in agreement with the present writer) that the choice of foods is not directly dependent upon their nutritional nature but rather upon the animal's subjective response.

According to the need-stimulus theory of drive the source of motivation is found in persistent stimulations from tissues in need, such as the contractions of an empty stomach or the persistent pain-pressure stimulations from the parched throat in thirst. According to the affective-determination theory persistent motivation comes from the proprioceptors when the organism is in a set with expectant tension.

When a rat is placed in an environmental situation (apparatus) to which he is well habituated there is reintegration in him a specific neuromuscular determination. This reintegration builds up a more or less persistent proprioceptive stimulation which furnishes physiological drive. But wholly apart from proprioceptive stimulation and preparatory adjustment the well-trained animal responds to environmental stimulations, immediately and automatically, with patterns of learned behavior which lead him to food. The food-seeking patterns may become so completely automatic that they resemble reflexes.

According to the need-stimulus theory the strength of drive varies with the degree of need. But it has been shown experimentally that the relation between the strength of the behavioral hunger drive and the period of food deprivation is not linear. The strength of behavioral drive reaches a peak after several

days of deprivation and then declines; but the need for food increases steadily with deprivation until death through starvation. Despite this difficulty one commonly reads of a 24-hour hunger drive or a 48-hour drive! One reason why the quantitative psychology of food-seeking motivation has been so backward and inexact lies in the fact that the strength of hunger and thirst has been controlled solely through deprivation, palatability relations being ignored.

According to the affective-determination theory the strength of behavioral drive, as actually observed and measured, varies with many conditions (36). There are three main groups of parameters: (1) Intra-organic conditions including specific hungers and non-appetitive constitutional factors. (2) Environmental conditions including palatability and non-palatability factors. (3) Feeding habits and attitudes already acquired by the organism. To control the strength of drive one should keep *all* of the factors constant except one which is experimentally varied. For example, the strength of drive might be controlled by varying the palatability level of the incentive food. One might vary only the concentration of saccharin solution presented as a reward to well-nourished, non-hungry rats (3, 10).

Any theory of food-seeking and food-selecting drive must explain the facts. The affective-determination theory offers a plausible explanation of facts brought to light in experiments upon food acceptance: the uniformity and stability and consistency of food preferences; the transitive series or hierarchies of preference which have been repeatedly found, the dependence of food acceptance upon the characteristics of the food object as well as upon the chemical state of the organism, the correlation between the observed strength

of behavioral drive and the measured level of palatability, the gross fact that adequate motivation can be obtained with a food incentive in the absence of bodily need, and similar facts. The need-stimulus theory simply does not offer satisfactory explanation for any of these facts.

Some related work. Bindra (4) believes that the motivation for hoarding food is the same as that for eating food and that a non-alimentary mechanism determines both hoarding and eating. Interestingly enough, he found that the number of units of food hoarded was greater when a wet mash containing saccharin was offered than when pellets of Purina Chow were presented. The sweet wet mash was preferred in hoarding even though the saccharin has no utility in meeting bodily need! It is of theoretical importance that the more palatable food evoked the greater activity of hoarding. This is in line with our repeated finding that the more palatable food evokes the greater rate of running.

Bindra's reference to a non-alimentary mechanism raises an interesting problem. A neuromuscular set with proprioceptive tension is a non-alimentary mechanism. It is likely, however, that the bodily preparation for a particular kind of food includes changes in the tonus of the smooth muscles of the alimentary tract and changes in the activity of salivary and gastric glands. It is the organism as a whole which is prepared for food. We would predict the existence of quantitative relations between the degree of salivary secretion and the palatability level of the food incentive. The relation between the alimentary and non-alimentary factors in food-seeking drive is something which needs to be studied experimentally.

Another paper, pertinent to our present discussion, is that of Elliott and Bousfield (7). After reviewing the facts

relative to deprivation these writers have pointed out that it is difficult to demonstrate any simple and general relation between deprivation and behavior. The various drives have similar behavioral effects and probably have similar bodily mechanisms.

In certain respects, Elliott and Bousfield argue, drives are like emotions. In both there are two basic mechanisms of motivation. First, there is a proprioceptive mechanism which builds up muscular tensions. In so far as can be determined from the available data, the effects of proprioceptive tension and hunger contractions are similar. In both there are volleys of afferent nerve impulses which result in the facilitation of skeletal reflexes and of central processes. One and the same mechanism may be assumed for proprioceptive tension and hunger contractions. Second, there is a sympathico-adrenal mechanism which operates in hunger and in other emergency conditions. These two mechanisms, the proprioceptive and the sympathico-adrenal, account satisfactorily, Elliott and Bousfield believe, for the varied behavioral effects of hunger.

We agree with their analysis so far as it goes. Our research to date, however, has tended to emphasize the first of these mechanisms—the proprioceptive mechanism. We believe that the selection of food is fundamentally a biochemical process and that its bodily mechanism is more general and more complex than is the sympathico-adrenal mechanism alone.

Relative to the proprioceptive mechanism a brief methodological paper by Geier (8) is of interest. Geier described a technique for measuring the bodily tension associated with expectation of food. He placed rats for one minute prior to feeding (or to non-feeding) in an activity wheel. By recording their activity he demonstrated that rats 'expecting' food made more revolutions per

minute than similar rats not 'expecting' food. Underlying this work is the assumption that when a rat is 'expecting' food a tension of expectancy is built up. The rat can reduce or work off this tension by running in an activity wheel. Geier's work is based upon Tolman's well-known hypothesis of expectation. Assuming the method to be sound, we would predict that rats 'expecting' a highly palatable food such as sucrose would be more active in the wheel than those 'expecting' a food of low palatability such as casein. An experimental test of this hypothesis could readily be made.

In concluding this section we point out that the above interpretation of food-seeking and food-selecting behavior recognizes the fundamental importance of affective arousal in the organization of drives. The theory is frankly hedonic. Affective arousal in the rat is assumed on the basis of the rats' behavior and human experience. Some day, we believe, affective arousal will be described objectively in terms of brain dynamics and the underlying biochemical processes. For the present the assumption of affective processes within the rat appears to be the simplest hypothesis for interpreting the available data upon relative food acceptance.

The assumption of affective processes has wider implications than those within the area of food acceptance. The assumption of affective arousal is fundamental in such broad fields of investigation as the study of pain avoidance, anxiety, neurosis, sexual behavior, as well as in the general theory of motivation.

The above analysis brings together three fundamental aspects of motivation which have heretofore been treated somewhat apart. First, psychological hedonism, an ancient doctrine, is implied by the assumption that affective processes organize determinations which

are expressed in behavior and that there is a quantitative relation between observed strength of drive and affective intensity. Second, the theory of organic set or determination has long been central in the analysis of motivation. In the present study we have assumed that determinations (organic sets) are organized to continue enjoyment and to relieve distress. Third, persistent organic stimulation has long been recognized as a factor in physiological drives. The present emphasis upon proprioceptive tension indicates a source of persistent drive stimulation in lieu of (or in addition to) the usual accounts of stimulations from tissues in need.

These three aspects of motivation— affective process, neuromuscular and neural determination (set), proprioceptive stimulation or tension—are, therefore, related to each other in the present theoretical analysis. Further, we have emphasized the fundamental importance of biochemical factors in the determination of relative food acceptance.

AFFECTIVE AROUSAL AND LEARNING

In current discussions of learning the word *reinforcement* frequently occurs. What does it mean? The writer, for one, does not know. The word suggests a strengthening similar to that due to practice, or training, but clearly the word does not refer to the effects of exercise as such.

The ingestion of food is said to 'reinforce' patterns of behavior which lead up to ingestion. In a recent paper presented to the American Psychological Association, the quantity of food consumed is accepted as an index of the quantity of 'reinforcement.' Here is reinforcement measured right down to the fraction of a gram! The relief of general hunger is commonly described as 'reinforcing.' The relief from anx-

iety, according to O. H. Mowrer, is 'reinforcing' since patterns of behavior which reduce anxiety are repeated and learned. What is reinforcement?

The word *reinforcement* appears to carry the implication that affective processes are importantly related to learning. But how are affective processes related to learning? The answer is not clear from current discussions. Obviously, certain stimulus-objects do not reinforce. Perhaps they are affectively indifferent (?). Other stimulus-objects relieve distress and this relief 'reinforces' behavior. Positive enjoyment, however, as well as relief from distress, appears to provide 'reinforcement.'

If we look at this matter historically, we find that for a good many centuries the pleasure-pain theory of learning was quite generally accepted. Affective processes were frankly recognized as being related to learning. In modern times Thorndike formulated his law of effect; affective processes were admitted in the form of satisfaction and annoyance. Under criticism Thorndike abandoned affective processes, largely because of their subjective nature, and stated the law of effect objectively in terms of behavior. Like the family cat, however, who was kicked out the back door and later slipped in at the front door, affective processes were ejected (or should we say evicted?) from American psychology. Soon it became respectable to talk about *reinforcement*. Have we been duped?

In considering the problem of affective processes as related to learning we will define learning as a modification of behavior and of neural organization which is produced through practice, or training. The making of an organized response is the *sine qua non* of learning. An animal must act to learn and he learns precisely the activity exercised. With practice, or training, an acquired pattern of response becomes

smoother, better organized, more readily elicited.

Now affective processes are not necessary for learning to occur. Sheer repetition when the affective state is indifferent may result in learning. Moreover, consciousness is not necessary for learning to occur. A decorticate dog (presumably unconscious) is capable of learning. Even the simultaneous excitation of two neurons may result in a functional change which can significantly be described as learning.

Since affective processes are not essential for learning, just how are they related to learning? In terms of brain dynamics we think of enjoyment as associated with the process of organizing patterns of response and with the maintaining of recently organized response patterns. We think of distress as related to a central disorganization produced through frustration, intense stimulation, and certain sensory excitations such as those from bitter substances. The relief from distress is related to the organizing and maintaining of patterns of response which produce relief.

Thus enjoyment, distress, and relief are intimately associated with the organizing and disorganizing of patterns of response. Is the *process of organizing* to be regarded as a form of learning? We think not. If *learning* is defined as the *process of organizing*, the definition of learning becomes so broad that it is practically useless in psychology. It is better to think of learning in terms of the fixation of organized response patterns through exercise. A single response may result in some learning, but practice and training imply the repetition of an organized response.

Of course, there are conditions other than affective arousal which lead to psychological organization and to disorganization. Gestalt psychologists have long stressed the fact that perceptual organization is determined by the configura-

tion of energy within the stimulus field as well as by the physical structure of the brain. Again, habits and attitudes which have already been learned are themselves factors in further psychological organization. Practice itself makes for a smoother, better integrated response, and is thus a factor in the development of psychological organization.

Enjoyment and the relief from distress, therefore, are conceived as intimately related to psychological organization and disorganization.

The relation between practice and affective arousal. If rats are given a series of runs on our apparatus for a single food incentive, their rate of running increases steadily with practice. For this reason the *absolute* rate of running is not a dependable index of the palatability level of the test-food. The *relative* rates of running for different foods, however, agree with the palatability ratings when practice is the same for all. If the frequency and distribution of runs are the same, rats at all levels of practice run consistently faster to a preferred food than to one which is not preferred. The results suggest that practice and palatability level are independent factors which determine the rate of running to food.

Several of our experiments throw light upon the relation between practice and palatability:

In one experiment an attempt was made to reverse the preference of sugar to casein by training the rats to run for casein alone, without choice. The general plan of the experiment was to give a series of brief tests of preference between sugar and casein. Practice in running for casein, the non-preferred food, was interspersed between these tests. The results showed clearly that the rate of running for casein increased steadily with practice but that practice

up to 1000 runs per rat did not disturb the initial preference for sugar. On the contrary, the percentage of preference for sugar increased steadily from test to test (despite the running for casein) until at the close of the experiment there was a 100 per cent preference for sugar. A control group without intervening practice also exhibited a consistent preferential trend toward a 100 per cent preference of sugar to casein (32).

In an earlier experiment under somewhat different conditions the opposite result had been obtained. The rats of one group had been trained in running to wheat and those of another group had been trained in running to sugar prior to any test of preference. When the preference between wheat and sugar was first tested the wheat-habituated rats continued to select wheat and the sugar-habituated rats continued to select sugar. During repeated tests the preference for wheat was stable but the preference for sugar weakened and with some animals it reversed. The results suggested that the particular diet of the experiment would support a stable wheat preference but not a stable sugar preference (28).

These two opposed results can be reconciled by recognizing that sugar and wheat are nearly equal in palatability and that casein is distinctly less palatable than either sugar or wheat (under dietary conditions of the experiment). If test-foods are nearly equal in palatability, practice may be temporarily effective in determining choice; but if the test-foods differ widely in the level of palatability, practice in running for the less palatable food is ineffective in changing a preferential selection. Practice may develop a food-accepting habit but palatability rests upon a chemical basis and is something which is independent of practice.

Other experiments with the preference technique leave no doubt concerning the

great importance of habit as a determiner of food selection.

In the introductory paragraphs of this paper we pointed out that animals *learn* a preferential discrimination and that the percentage of preference increases with practice. In early experiments we used the technique of substituting one pair of test-foods for another or of abruptly changing one member of the pair. This technique revealed abrupt changes in the percentage of preference followed by gradual preferential trends. In one such experiment, for example, tests of preference were made with sugar and three other test-foods; sugar was consistently preferred to them all. Then milk (a new food) was tested with sugar. At the start the animals continued to select sugar but with continued testing the preference weakened and then reversed. The last tests revealed an unmistakable preference of milk to sugar. The curve of preferential trend was in the form of a gradual wave first above and then below the 50 per cent sugar-acceptance line. This curve of preferential trend can be explained by assuming that the rats were habituated to selecting sugar, a highly palatable food, before milk was introduced. When milk, the most palatable food of all, was presented the sugar-selecting habit gradually weakened and the milk-selecting habit gradually strengthened (23).

We noted above that a preference can be reversed either by satiating rats upon the preferred food or by depriving them of the non-preferred food. But in neither case does the reversal occur at once. On the contrary, there are gradual changes in the relative frequency of selecting the two foods until finally, with practice, the original preference is reversed. The gradualness of these preferential changes indicates that a percentage of preference is dependent upon practice and that for this reason

a fixed percentage of preference cannot be used as a univocal index of a difference in palatability.

In the experiment of Young and Chaplin (37) the continued preference of sugar to casein, despite a marked bodily need for casein, was finally explained in terms of habit. The interpretation affirms that an established preferential habit can regulate the selection of food independently of bodily need and even contrary to need and to normal palatability relations. When the rats in this experiment were forced to form a new preferential habit on a new kind of apparatus they at once selected casein in preference to sugar. The new preferential habit revealed the true palatability relations under the changed dietary and testing conditions. An established feeding habit, therefore, may dominate the choice of food irrespective of bodily need and irrespective of the chemically-determined and stable relationships of palatability.

Perhaps this result can be regarded as an instance of the functional autonomy of habits—the persistence of habits despite change in the underlying conditions of need. Further examples of the dominance of habit mechanisms despite changes of internal organic state are to be found in the experiments of Spence and Lippitt (19) and Brogden (6) which will be discussed below.

The total evidence indicates clearly that a habit mechanism may regulate the preferential selection of food independently of palatability. A habit mechanism may even obscure the true relationships of palatability and for this reason practice must be carefully controlled before making any generalization about palatability. Practice is one thing; affective arousal is something else.

Practice and affective intensity as independent determinants of the strength

of behavioral drive. Experiments upon food acceptance have shown clearly that the strength of behavioral drive in running to food depends upon at least two independently variable conditions. First, practice is an important determinant of the rate of running to food. It is beyond question that the strength of an acquired food-seeking drive varies directly with the frequency and temporal distribution of runs. Second, there is a direct quantitative relation between the intensity of affective arousal (as shown by tests of preference) and the strength of behavioral drive toward a specific food (as measured by the rate of running and the latency of food acceptance) (33, 34).

In other words, the measured strength of behavioral drive varies both with practice and with affective intensity. These two determinants of the strength of drive are relatively independent of each other. Evidence that practice and affective intensity are independent determinants of the strength of drive can be summed up in the following three points:

1. It has been repeatedly observed that practice brings an increase in the percentage of choices of the preferred food. Practice raises the percentage of choices to a ceiling somewhere between 50 and 100 per cent. But practice does not change the palatability relations among a group of test-foods. In one experiment three test-foods were used and the three pairs of foods were given equal practice. All the percentages of preference changed with practice but the hierarchy of relative palatability remained the same at every stage of practice (33). Practice revealed the preferential relations with increasing clarity and definiteness, but practice did not change the chemically-determined relationships of palatability. Practice and palatability are distinct and independent

determinants of the percentage of preference.

2. When rats are run on our apparatus for a single food, without choice, the rate of running steadily increases with practice. If the daily runs are omitted for a time (as during a vacation period) the rate of running is lower after the pause. There can be no doubt that the rate of running for a single food varies with the frequency, the recency, and the temporal distribution of runs. Now if the two foods which differ markedly in palatability are employed as incentives, and the frequency and distribution of runs are the same for both, the rats run consistently faster for the preferred food. At all stages of practice the preferred food evokes the higher rate of running. In other words, to repeat, the rate of running for a single food is dependent upon two independently variable factors: the level of palatability (intensity of affective arousal) and the number and temporal distribution of runs (33).

3. In one experiment rats were given a single run per day at the same hour of day to keep the factor of practice constant. Under these conditions it was found that rats running to sugar ran consistently faster *at all stages of practice* than those running to casein. These incentive differences in the rate of running cannot be attributed to practice since the factor of practice was constant. The differences depend upon the quality of the reward and they are motivational in nature.

To equalize motivational differences we added together, cumulatively, the total daily running times for each rat regardless of the kind of reward, and then we called the total time for each rat unity. This procedure equalized motivational differences due to the kind of food and to constitutional factors which are reflected in the speed of locomotion. The total cumulative ap-

proach time for each animal was then divided into thirds. The number of runs made by a rat during the first third, the second third, and the third third of his total cumulative time was determined from the data sheets. The group data were plotted. The curves showed an increase in the number of runs with practice from one third to the next third of the running time. But under these conditions the practice function was the same for all three test-foods. The rats did not *learn* faster for one food than for another. We concluded that *learning* is dependent upon the number and distribution of runs and that when practice is held constant the *rate of learning* does not vary with the palatability of the test-food. The *rate of running*, however, is directly related to palatability and this relation appeared clearly at all stages of practice. The rate of running is dependent upon both motivation and practice which are independent variables (33, 34).

This conclusion may appear not to agree with common sense expectation based upon a confusion of performance (which depends upon many factors including exercise) and learning (which depends upon exercise alone). The teacher knows that Johnnie works his arithmetic better for a good reward than for a bad one. Of course, if our rats had been run continuously for 15 minutes daily, the sugar-incentive rats would have made more runs during the period than casein-incentive animals. For this reason alone they would have *learned* faster with a sugar incentive. But in a fair comparison of incentives the number and temporal distribution of runs must be held constant and only the one factor in which we are interested (palatability) varied.

The conclusion can be stated as a paradox: The rat learns to *run faster* to sugar than to casein, but he does not

learn faster to run to one food than to another.

The conclusion to which we are drawn has a clear bearing upon the much discussed law of effect (14). It is our view that the laws of learning are entirely laws of exercise, practice or training, and that affective arousal is only secondarily related to learning. Affective arousal is related primarily to the organizing and disorganizing of psychological processes. If an organized response is made, to prolong enjoyment or relieve distress, this organized response leaves after it some neural trace. This neural trace is fixated by exercise rather than by affective processes.

The above lines of evidence and argument lead to a single conclusion: The strength of behavioral drive in food-seeking depends upon two relatively independent factors—exercise and the intensity of affective arousal.

The acquisition and redintegration of food-seeking determinations. A positive or pleasant affective arousal results in an organized response to continue or preserve the enjoyment. A negative or unpleasant affective arousal results in various signs of psychological disorganization. The relief from distress is an affective process which organizes behavior to continue or preserve relief.

Any response which an organism makes may leave after it some physical change within the nervous system which is the physical basis of learning.

Positive affective processes lead to the organization of neural determinations which are shown in persistent purposive behavior. An intense enjoyment organizes a strong drive; a less intense enjoyment organizes a less strong drive. In every day terms we might say that there is an identity between degree of enjoyment and degree of desire.

When positive affective arousal is repeated day after day the organizing

process is repeated. At this point learning comes into the picture. When a naïve rat is placed in our apparatus he explores timidly and finds the food reward seemingly by accident. When a practiced rat is placed in the apparatus and later released from the starting-box he runs promptly and smoothly to the food. Clearly he has learned something. With the practiced animal the stimulus-patterns from the apparatus redintegrate an acquired determination to run to food. Possibly there is an expectancy of a particular kind of food. The expectant set is shown by occasional attempts to raise the door prematurely and by the bodily orientation toward the door and the food. But even when these activities do not occur the animal still runs promptly to the food when the door is opened. Visual and auditory stimulations from the apparatus presumably release the acquired purposive behavior.

The rat in the starting-box awaiting release resembles an automobile driver poised before a traffic light. Flashing of the green light releases a pattern of behavior for which the subject is already prepared.

There can be little doubt that environmental stimulus-patterns redintegrate food-seeking determinations in the rat. A question of considerable theoretical importance, however, is the one considered in the next section.

Can the organic state redintegrate appropriate food-seeking behavior? Does the hungry animal seek food and the thirsty animal seek water in one and the same environment? To what extent do bodily needs act selectively in building up appropriate food-seeking determinations?

The early experiments of Hull and Leeper demonstrate that rats can learn to take one path to food when hungry and another path to water when thirsty.

Hull (11) argued that the explanation of this discrimination was in the difference between the organic stimulus-patterns of hunger and thirst. Through conditioning, he believed, the animal learned to take one turn in the presence of an environment plus hunger and another turn in the presence of the same environment plus thirst.

Kendler (12) has criticized Hull's interpretation. Kendler deprived rats of solid food and water so that at the time of training they were both hungry and thirsty. He trained these animals in a simple T-maze with water in one goal box and food in the other. The experimental procedure was planned so that all rats would have equal opportunity to explore both goal boxes. In the critical test series the rats were made either hungry or thirsty but not both hungry and thirsty.

Kendler found that the hungry rats were able to go directly to food and the thirsty rats to water. In view of their known organic state their choice of pathway was clearly appropriate. Kendler argued that since the training had been under a single physiological drive (that produced by inner stimulation from simultaneous hunger and thirst), the discrimination of pathway could not be referred to some difference between the organic stimulus-patterns arising either from hunger or from thirst. Consequently, Kendler concluded, Hull's explanation of the hunger-thirst discrimination is not correct.

Our interpretation of the facts would be as follows: During the training period the hungry-thirsty rats enjoyed nibbles of food in one place and sips of water in another place. On the basis of an immediate affective arousal two independent food-going determinations were organized and they were both equally practiced. One determination directed the animal to solid food, the other determination to water. At the

time of the critical test there was clearly some selective factor. What is it? This factor, we believe, is the state of satiation produced by the experimenter. The hungry rats were also water-satiated; the thirsty rats were also food-satiated. Whatever satiation may ultimately turn out to be, it is obviously an organic condition which inhibits the acceptance of a particular kind of nutrient. Hence, since the water-going and food-going determinations were equally practiced at the time of the test, the state of satiation would act and did act selectively by weakening the inappropriate determination. Consequently the hungry rats were univocally determined to go to food and the thirsty animals to water.

Another experiment which is apropos is that of Spence and Lippitt (19). These investigators trained rats to run a Y-maze under thirst motivation. One path led to water. The other path led to food (for half of the rats) or to an empty box (for the other half). Inasmuch as the rats were food-satiated, they did not eat when they discovered the food in the food box. In the critical test series the internal motivation was changed. The rats were now made hungry but satiated upon water.

Spence and Lippitt found that on the first trial the hungry animals inappropriately ran down the water alley to water. In further runs the hungry rats learned to run to food but they learned no faster than the animals which had never found food there during the training period. Mere 'knowledge' based upon sensory inspection of the food but without ingestion was of no avail in re-learning to run to food instead of to water.

Our interpretation of the Spence-Lippitt result is as follows: During training there was no hunger, no food acceptance, no affective arousal through contact with food, and hence no ac-

quired determination to run to food. There must have been some perceptual organization relative to food ('knowledge') but a neural set to run to food was not organized. On the other hand, through enjoyment of sips of water there was definitely organized in all rats a water-seeking determination. This determination was fixated through exercise. When the organic state was changed from thirst to hunger and the hungry animals were placed in the familiar apparatus the environmental stimulus-patterns redintegrated the only purposive determination which had been learned—that which was made manifest by running to water. With further trials the hungry rats organized and practiced a food-seeking determination. The positive affective arousal through contact with food was necessary for this purposive determination to develop.

As to the possibility of an effective 'knowledge' factor, it is our opinion that the Spence-Lippitt experiment does not disprove Professor Tolman's hypothesis. In a fair test there should be equivalent 'knowledge' of the food location and of the water location prior to the development of any selective motivation. This condition was not met by the Spence-Lippitt experiment.

In the present connection an experiment by Brogden (6) has theoretical interest. Brogden found that the rate of extinction of a conditioned leg flexion was nearly the same with hungry and satiated dogs. He demonstrated that stimulations from the apparatus which delivered the food were more important in preserving a learned response than the organic state of hunger or satiety. Brogden interpreted his findings in terms of Anderson's theory of externalization of drive.

Our interpretation would be somewhat different. The leg flexion under the conditions of Brogden's experiment was in the first place organized under

affective conditions—relief from pain and later enjoyment of food. With practice this response became automatic and controlled by environmental conditions. The response became a habit regulated by an acquired neural mechanism. Under these conditions a change from hunger to satiety should not be expected to make very much difference in the extinction time of the conditioned response. A problem arises only when we assume that the original motivation for food acceptance was the gastric hunger tension.

In concluding the present section of our discussion the writer expresses the view that positive or pleasant affective processes lead immediately to the organization of central neural determinations which are expressed in purposive behavior. Behavior moves to sustain and preserve enjoyment as well as to relieve distress. Affective processes are the *raison d'être* of purposive activity. By its very nature enjoyment is something to be maintained or regained; distress is something to be relieved or avoided. The organization of behavior to preserve enjoyment and to relieve distress implies a corresponding neural organization of response patterns. Quite frankly we believe that there is an hedonic steering, directing, principle.

We do not claim that affective arousal is the *sine qua non* of learning; nor that affective arousal 'reinforces' certain behavioral patterns. We claim rather that patterns of purposive behavior are *organized* to preserve enjoyment and to relieve distress, and that enjoyment and relief are *organizing* processes. Further, we recognize other principles of organization and disorganization than the hedonic principle.

GENERAL CONCLUSIONS

The present paper is a study of the theoretical implications of the writer's experiments upon food acceptance and

the relation of this work to current views concerning food-seeking drive, affective process, and learning. On the basis of the discussion the following general conclusions are drawn:

1. Affective processes exist in the rat as truly as in man. When the head receptors, especially those of taste and touch and smell, come in contact with a food there is an affective arousal which we have designated as enjoyment. Different intensities or degrees of enjoyment are revealed directly by the feeding behavior of rats and by tests of preference. Distress produced by deprivation and the relief of distress through food ingestion are also affective processes which are importantly related to food acceptance.

2. An hedonic theory of drive is proposed. Specific food-seeking determinations are organized within the nervous system to preserve the enjoyment of foods and to relieve organic distress produced by dietary deprivation. In general, rats develop drives to run to foods which they *like* (find enjoyable) rather than to foods which they *need* (require nutritionally). There is, however, a positive correlation between what rats *like* and what they *need* but not a one to one relation.

3. The strength of drive in running to a food varies directly with the degree of enjoyment (intensity of affective arousal) of that food. Rats run faster in approaching a highly palatable food and accept it more promptly than in approaching a less palatable food. Consistent differences of palatability are apparent at all levels of practice.

4. Affective arousal, conceived in terms of brain dynamics and resting upon biochemical conditions, is intimately related to the organizing or disorganizing of psychological processes. Behavioral patterns are organized which continue and preserve enjoyment and relieve distress.

5. Learning is defined as a modification of behavior and of neural organization which depends upon exercise, particularly upon practice or training. The making of an organized response, regardless of how it became organized and regardless of its motivation, results in learning.

6. The strength of a food-seeking drive, as measured by the rate of running to food and the latency of food acceptance and by preferential food selection, depends upon two independent variables: the intensity of affective arousal by food contacts, and the number and temporal distribution of runs to food.

These same two factors— affective intensity and practice— regulate the preferential food selections of the rat.

7. The intensity of affective arousal is correlated directly with the strength of food-seeking drive but not at all with the rate of learning. If the frequency and distribution of runs are held constant, rats do not *learn* faster to run to one kind of food than to another. At all stages of practice, however, rats *run* faster to the more palatable food and they accept it more promptly than the less palatable food. This means that affectivity is primarily related to motivation and secondarily to learning.

8. Specific food-seeking and food-selecting determinations are developed through practice. When a trained rat is placed in a familiar apparatus the environmental stimulus-patterns re-integrate an organic set of preparation and expectancy with alimentary and proprioceptive components. There is a proprioceptive tension which, we assume, varies in degree with the strength of drive. Moreover, rats act as if they were expecting a particular kind of food and not just food in general.

9. Relative food acceptance can be investigated as a part of an objective psychology of the affective processes

with a minimum of hypothesis. The parameters of food acceptance form three main groups: intra-organic conditions, environmental (palatability and non-palatability) conditions, feeding habits and attitudes. The theoretical views expressed above rest squarely upon the analysis of laboratory findings and a test of their adequacy can be made in further investigations.

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