followed in 3 to 5 days. The few animals that survived this period grew at very slow rates, weighing only 12 to 15 g at 21 days. This syndrome was observed in animals fed either a diet of cow's milk, or of rat's milk obtained by the machine milking of lactating mothers (*5*).

Both the feeding behavior of infant rats in our colony as well as the strong impulse to suckle during intubation feeding indicated that there might be some relation between suckling and emptying of the stomach. To test this, two groups of eight animals were fed five times daily and then suckled on lactating females twice daily. No evidence of bloat or increased stomach-emptying time was observed.

Since the purpose of these studies was to develop a technique for feeding partially-purified diets, the use of lactating females as a source of suckling was not feasible. Therefore, a similar study was performed with nonlactating foster mothers.

These female rats had had at least one litter that had been weaned at least 3 weeks previously. To demonstrate the absence of lactation, the potential foster mother was given oxytocin and milked by machine for 3 to 7 days. No milk secretion was observed. In addition, no milk was found in the stomachs of 7-day-old rats allowed to nurse on these mothers. Since Bruce (*6*) had reported no induction of milk secretion until the 35th day of strong suckling in female rats allowed to rest 24 days after weaning of their litters, the nonlactating foster mothers could be used in 21-day experiments without secreting milk.

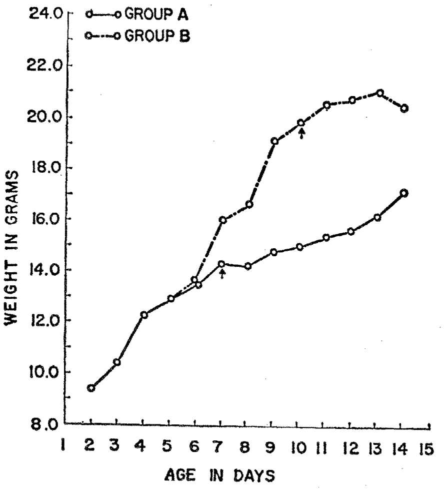

Fig. 1. The growth of neonatal rats fed rat's milk or cow's milk by tube and allowed to suckle on nonlactating female rats.

The results of this test were essentially the same as those obtained with lactating mothers. No evidence of bloat or of failure of the stomach to empty was observed. Growth, however, was reduced. This appeared to be related to the quantity of rat's milk fed rather than to the feeding technique itself.

Ten neonatal animals (6 to 7 g) were randomly assigned to each nonlactating foster mother. A number of additional foster mothers were available to replace any foster mother not accepting her litter. The infant rats were fed with a 24-gauge ball-tipped needle. During the first 24-hour period, they were fed 0.20 to 0.30 ml of diet at each of 11 feedings. In the next 48-hour period, the number of feedings was reduced to nine per 24 hours and the amount at each feeding was increased to 0.30 to 0.40 ml. After this initial 72-hour period, there were seven feedings during each 24-hour period and the volume was increased from 0.4 ml to as much as 1.0 ml per feeding.

While it is rarely necessary to stimulate evacuation of urine and feces by stroking the perianal area of these young animals, this must be done if the foster mothers are not accepting their litters. For this reason, the litters of animals must be carefully observed during the initial 48-hour period of the experiment. If the animals are scattered or appear cold, the foster mother must be replaced immediately.

Some results are illustrated in Fig. 1. Group A, fed rat's milk by tube from day 2 to day 7, grew as well during this period as animals fed solely by lactating females (group B, days 2 through 5). On day 5, group B was removed from the lactating females and fed rat's milk by tube and allowed to suckle on nonlactating females. No decrease in growth rate resulted. The growth of both groups was depressed when a cow's milk formula replaced the rat's milk diet (day 7 for group A and day 10 for group B).

Thus, the artificial feeding technique will allow normal growth in infant rats; and it provides a means of feeding semipurified and synthetic diets to the newborn rat (*7*).

SANFORD A. MILLER
HENRY A. DYMSZA

Department of Nutrition and Food Science, Massachusetts Institute of Technology, Cambridge

References and Notes

1. See, for example, M. W. Galgan and M. E. Ensenger, *J. Animal Sci.* **15**, 811 (1956); D. E. Becker, M. C. Wesheim, S. Terrill, A. H. Jensen, *ibid.* **14**, 642 (1955); H. D. Hutchinson, A. Jensen, S. Terrill, D. Becker, H. Norton, *ibid.* **16**, 553 (1957).
2. See, for example, the series of papers with pigs and chickens by R. A. McCance and his associates, the most recent of which is V. Cabak, G. A. Gresham, R. A. McCance, *Brit. J. Nutr.* **16**, 635 (1962); J. E. Slater and E. M. Widdowson, *ibid.*, p. 339, with kittens; E. M. Widdowson and R. A. McCance, *Proc. Roy. Soc. London, Ser. B* **152**, 188 (1960); F. W. Heggeness, D. Bindschadler, J. Chadwick, P. Conklin, S. Hulnick, M. Oaks, *J. Nutr.* **75**, 39 (1961), with rats.
3. H. Prechtl and W. M. Schleidt, *Z. Vergleich. Physiol.* **33**, 62 (1951).
4. J. Pleasants, *Ann. N.Y. Acad. Sci.* **78**, 116 (1959).
5. The milking machine used was modified from that of W. W. Nelson *et al.*, *J. Nutr.* **44**, 535 (1951). The animals received 2.0 units of oxytocin 5 to 10 minutes before milking. From 3 to 7 ml of milk could be obtained per milking after the 7th day of lactation.
6. H. M. Bruce, *J. Reprod. Fertility* **2**, 17 (1961).
7. Contribution No. 541 from the department of nutrition and food science, Massachusetts Institute of Technology. Supported in part by the National Science Foundation, grant No. 615889. We thank Dorice M. Czajka for invaluable assistance.

15 May 1963

Food versus Perceptual Complexity as Rewards for Rats Previously Subjected to Sensory Deprivation

Abstract. *Rats raised in darkness or in a constantly lighted white cage go to food in a T-maze if the food is located in a checkerboard goal. They do not go to food if the food is located in a visually less complex, half-black, half-white goal. Normally raised rats go to food regardless of the visual complexity of the goal.*

Theory and research in the study of motivation assume that a hungry animal will learn those responses that produce food and cease making responses that do not produce food. Drive theories, especially, assume that operations such as deprivation of food or water are sufficient conditions for producing motivation, and that the presence of food or water after a particular response is a sufficient condition for learning that response, provided enough learning trials have been given. This report questions the assumption that food reward is a *uniformly* sufficient condition for reinforcing behavior in hungry animals (*1*). Specifically, it is asked if hungry animals, reared in an environment where they were deprived of varied visual stimulation during behavioral development, will prefer to eat food, or prefer to have commerce with visually complex stimuli.

Thirty-six hooded rats were weaned and placed in cages made out of 1-qt metal fruit cans, one rat per can, on the evening of the day on which their eyes opened. The median age of eye-opening was 15 days. These animals remained in the cans for the next 45 days. Half of the cans were painted white. A 6-volt light bulb, bolted to the inside of the can top, provided 24-hour illumination for each white can. The open end of the can was placed on hardware cloth, which served as the bottom of the cage. The animals could not see out of the side or top of the cage, and could see brown paper, only, through the hardware cloth. The other cans were painted black, and were placed in a different, completely dark room. The dark-reared animals received light (.01 mlam) for 15 minutes on each day. The experimental animals, subjected to sensory deprivation, thus consisted of (i) 18 animals, half male and half female, reared in a constantly lighted, white cage, and (ii) 18 animals, half male and half female, reared in a constantly dark, black cage. Control animals, ten males and ten females, were also weaned on the day that their eyes opened, and were immediately placed, three rats per cage, in the normal colony environment.

After the 45th day of sensory deprivation, the deprived rats were placed in colony cages under the identical conditions of the normally reared animals. At the time of this experiment, the rats were 125 to 140 days old. Therefore, the deprived animals had been living under normal visual stimulating conditions for 65 to 80 days. The subjects had not been deprived of food or water, or subjected to any procedures involving electric shock or other noxious stimuli.

The apparatus was a wooden T-maze with a 6- by 12-inch start box, a 6- by 12-inch straight alley from start-box to the end of the choice-point area, and 6- by 24-inch detachable goal arms. The floor and walls of the start-box and straight alley were unpainted masonite. One of the goal arms was half black and half white. One wall was white, the other black. Half of the floor area, that adjacent to the black wall, was black, while the floor adjacent to the white wall was white. This goal arm is referred to as the *simple*-stimulus goal. The floor and walls of the second goal arm contained a black-and-white checkerboard pattern. There were approximately equal numbers of black and white 1-inch squares in the pattern. This goal arm is referred to as the *complex*-stimulus goal.

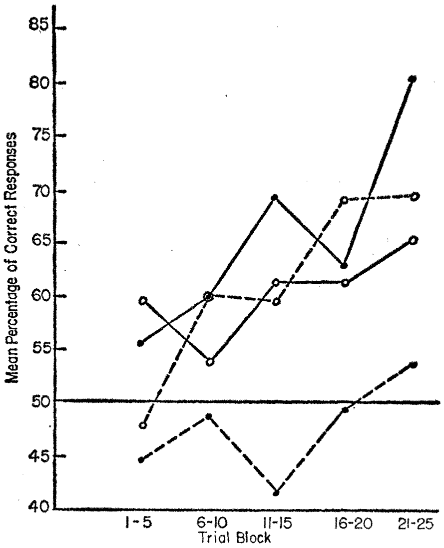

Fig. 1. Percent of subjects in each group going to the goal arm containing food on each trial, averaged over blocks of five trials. Solid line, filled circles: rats subjected to sensory deprivation, food offered at patterned goal; dashed line, filled circles: rats subjected to sensory deprivation, food offered at half-black, half-white goal; solid line, open circles: normal rats, food offered at patterned goal; dashed line, open circles: normal rats, food offered at half-black, half-white goal.

For half of the experimental animals and half of the control group, food was placed in the simple-stimulus goal. For the other half of the subjects in each rearing condition, food was placed in the complex-stimulus goal. Thus, half of the rats received food in the half-black, half-white goal if they chose that arm on a trial, while the remaining half received food in the checkerboard-patterned goal.

Twenty-five massed trials were given to each subject on one day. The goal arm containing food was on the right or left side of the maze on any trial as determined by a random schedule.

Two days before the start of experimental trials the animals were deprived of food, but not of water. After 24 hours of food deprivation, the animals were adapted to the maze start-box and choice-point area, and were allowed to eat 15 of the food pellets (45 mg) used as reinforcement, which were scattered about the maze floor at the choice point. The rat could neither see into, nor enter, either goal arm. This adaptation period lasted for 10 minutes. Experimental trials began 24 hours after adaptation. The subject received no food between the adaptation and test periods.

Immediately before the start of the first experimental trial, the subject was placed in the goal arm which would contain food on his test trials. Two pellets were placed in a small cup at the back of the goal arm. The subject was allowed 1 minute to eat the pellets and to explore the goal area. Trial No. 1 commenced 45 seconds after the end of this pretrial feeding period.

On each experimental trial the animal was allowed a maximum of 5 minutes to leave the start-box and enter one of the goal arms. A choice response was defined as entering the goal far enough so that the experimenter could close the goal-box door, touching no more than the rat's tail. After a choice, the animal was left in the goal arm for 30 seconds. The time between trials was 45 seconds.

The difference in number of correct responses, defined as choice of the goal containing food, between males and females was not significant. The difference between animals reared in the constantly lighted, white cans, and in the constantly dark, black cans, was also not significant. The interactions of sex, and white versus black rearing cages, with the goal-stimulus complexity variable were also not significant (all $P > .25$). Therefore, the data are pooled for males and females, and for both black and white rearing cages.

The mean number of correct responses on the 25 trials made by subjects in each rearing and goal-stimulus condition are as follows: (i) sensory deprivation, food in checkerboard goal, 16.6; (ii) sensory deprivation, food in half-black, half-white goal, 12.1; (iii) normal rearing, checkerboard goal, 15.3; and (iv) normal rearing, half-black, half-white goal, 15.5. Analysis of variance indicates that goal stimulus and the goal stimulus × rearing condition interaction are statistically significant (both $P < .01$). Thus the mean of 15.9 correct responses for all subjects that could obtain food at the checkerboard goal is significantly higher than the mean of 13.8 for the subjects that could obtain food at the simple-stimulus goal. The interaction of rearing condition and goal stimulus is produced because the mean number of responses to food by animals reared in sensory deprivation and tested with food in the simple-stimulus goal is significantly lower than the means for the other three groups.

A second breakdown of the data is shown in Fig. 1. This figure presents the mean percentage of correct responses on each trial for each of the four groups, averaged in blocks of five trials. The striking finding illustrated here is that little or no learning to go to food occurred in the group reared in sensory deprivation that received food in the simple-stimulus goal. In fact, the first four points for this group are either at or below the 50-percent performance level expected on the basis of chance. To further illustrate the nature of this finding, on 21 out of the 25 trials a majority of the subjects in this group chose the checkerboard goal rather than the half-black, half-white goal containing food ($P < .01$). All curves for the other groups show the typical increasing function characteristic of learning data. It is also instructive to note that on the first block of trials even the normally reared animals tested with food on the simple-stimulus side exhibit a tendency to choose the more complex, checkerboard stimulus.

These results reveal one major empirical fact. Under the conditions of this experiment, food is not a uniformly reinforcing substance serving to increase the probability of responses associated with it. If the rat has been reared in visual sensory deprivation, even though he has not been subjected to sensory deprivation during his adult life, he does not prefer a response alternative leading to food. Instead, he tends to choose a response alternative leading to a more perceptually complex, stimulating situation. Further, these data hint, although they do not show as clearly, that, for an animal subjected to sensory deprivation, the probability of going to food is higher than that for a normally reared animal if food is found in a complex visual-stimulus situation.

One problem concerning effects of sensory deprivation might be raised to question these results. The procedure used may have detrimentally affected the vision of the visually deprived animals. This problem is answered indirectly by the fact that the animals subjected to sensory deprivation and receiving food in the checkerboard goal *did* discriminate between the two goal stimuli. Thus, although retinal damage may have occurred, it was not sufficient to eliminate the subjects' ability to make a pattern discrimination.

If they can be replicated, results such as were found in this study must motivate a change in some of the current thinking concerning the necessary and sufficient conditions for choice behavior and for reinforcement. In the light of these data, the so-called "primary" biological needs, as such, do not appear to be the uniformly sufficient, let alone the necessary, conditions for motivation that have been assumed in the past. And, substances satisfying these "primary" biological needs do not appear to be the generally sufficient conditions thought to reinforce behavior and lead to learning.

The findings of this study are consistent with a number of investigations and formulations, such as the work of Harlow, Dember, and Levin and Forgays (*2*). Their reports, concerned with the so-called curiosity, exploratory, and/or manipulatory motives, illustrate the importance of temporal changes in stimulation, and the complexity of environmental stimulation as determinants of the activation and persistence of approach responses. The present study expands on this earlier work, indicating that (i) need for perceptual experience, like need for food, may involve biological processes just as basic as the classical "primary" biological needs; and (ii) the effects of early perceptual deprivation on later behavior may persist, in the form of an extremely strong motive to respond to complex stimulation, throughout the life of the organism (*3*).

GENE P. SACKETT[*]
PATRICIA KEITH-LEE
ROBERT TREAT
Psychology Department, Claremont Graduate School, Claremont, California

References and Notes

1. Some examples of theories leaning heavily on basic biological needs as sources of motivation include the following: C. L. Hull, *Principles of Behavior* (Appleton-Century-Crofts, New York, 1943); J. S. Brown, *The Motivation of Behavior* (McGraw-Hill, New York, 1961); ——— and O. H. Mowrer, *Learning Theory and Behavior* (Wiley, New York, 1961).
2. H. F. Harlow, *Psychol. Rev.* **60**, 23 (1953); ——— and G. E. McClearn, *J. Comp. Physiol. Psychol.* **47**, 73 (1954); H. F. Harlow, N. C. Blazek, G. E. McClearn, *ibid.* **49**, 444 (1956); W. N. Dember, *ibid.*, p. 93; H. Levin and D. G. Forgays, *ibid.* **53**, 194 (1960).
3. A paper based on this study was read by one of us (G.P.S.) at the Midwestern Psychological Association meeting, Chicago, 1963.

[*] Present address: Primate Laboratory, University of Wisconsin, Madison.

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Nutritional Relationships among Certain Filamentous Fungi and a Marine Nematode

Abstract. *A marine form of nematode,* Aphelenchoides *sp., can develop and reproduce effectively on viable mycelia of various filamentous fungi including certain widespread marine species. The efficiency of utilization of fungal mycelium by the animal, based on the ratio of the number of nematodes to the dry weight of fungal mycelium, varies greatly among fungi, from less than 100 to as much as 5000 for several of the marine species studied.*

The various reported associations between thalassiomycetes (*1*) and metazoans in the marine environment (*2*) suggest the diversity of biological activity of this mycota. The major portion of this work has involved studies of parasitic or pathogenic fungi, mostly Phycomycetes, except for a series of publications dealing with possible interrelationships between lignicolous fungi and wood-boring animals (*2*). The significance of these interrelationships has been subject to considerable speculation, although there are few detailed quantitative studies evaluating the activity of filamentous fungi in the growth and reproduction of marine animals. During a survey for the possible occurrence of marine predacious (nematode-capturing) fungi, observed activity within a fungus-nematode complex suggested the need for further examination of the beneficial effect of the fungal mycelia on the associated animal population.

Fungi were isolated from portions of various substrates, including submerged wood panels and pieces of sponges (both used as specific fungal baits), vascular plant and algal tissue, encrusted shells, coral pieces, rocks, and sediments, and were transferred to sea water agar supplemented with 100 mg chloroamphenicol per liter to inhibit bacterial growth. A diverse population of deuteromycetous fungi rapidly colonized the medium. Often, the development of these fungi was associated with active growth of species of marine nematodes. One plate exhibiting growth of a fungus, identified (*3*) as *Dendryphiella arenaria* Nicot, a salt-tolerant species originally isolated from intertidal sand (*4*), also showed a stylet-