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EFFECTS OF PALATABILITY OF FOOD ON THE CONDITIONING OF HUNGER IN RATS

by

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ABSTRACT

EFFECTS OF PALATABILITY OF FOOD ON THE CONDITIONING OF HUNGER IN RATS

Elizabeth Yates Hill
Old Dominion University, 1983
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An experiment was conducted to study the association of foods of different levels of palatability and environmental events present during eating. Rats were exposed to different foods in a start box and then allowed to run to a goal box containing food of a lesser or equal palatability. All animals showed a decrease in latency to eat in the start box and an increase in the amount of food consumed in the start box, with no significant differences in treatment groups at the end of conditioning. Although all groups, including the control group did run faster and eat more over days of conditioning, there were no significant differences in the motivation of the animals to run to food or the amount of food consumed in the goal box, as a function of the conditioning food. Apparently there were no lasting significant effects of the differences in palatability on the conditioning of hunger. These observations are discussed in terms of other literature showing an inconsistency of positive evidence for conditioned hunger.

ACKNOWLEDGEMENTS

I would like to extend my special thanks to my director, Dr. Stephen B. Klein for his guidance and motivation of this project and most of all for his continuing faith in my abilities. I would also like to thank the other members of my committee, Dr. Peter Mikulka and Dr. Barbara Winstead for their suggestions and direction of the research and writing. And to my family, I extend my appreciation for their understanding of the time and commitment involved.

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A friend told me a story about her cat, Sadie, and how the cat helped with the building of an additional room to her home. It seems this was a well-fed cat who ate canned tuna with gusto and always knew when it was her time to eat by the sound of the can opener. When my friend added a new room to her house, they discovered that they had a problem getting the wire from the stereo speakers in the addition to the stereo set. In order to get the wires in place, they would have to go through an enclosed space 12" wide, 18" deep and 16' in length. There is a 90° turn about half-way through the length of the space. The space is completely enclosed except for 6" circular openings in each room and runs along the ceiling of both the kitchen and the new room. It seemed that they would have to tear down a wall to accomplish this goal.

After much deliberation and with the builder standing by shaking his head, my friend came up with an ingenious solution. She attached one end of the wire to Sadie's cat collar, the cat was then hoisted up into one end of the enclosed space in the new room. At the same time, the can opener in the kitchen was turned on and Sadie rapidly moved from the opening in the new room to the opening in the kitchen. Obviously, the cat's response to the can opener enabled her to travel the desired distance and run the wires from the new addition to the stereo set. We will next discover why the cat responded to the can opener when she was not hungry.

INTRODUCTION

Two views of why animals and people eat when they are not biologically deprived have been proposed. In one approach Hull (1943) suggested that environmental stimuli could acquire the ability to produce hunger through the classical conditioning process. The conditioning of hunger assumes that if a neutral stimulus (the sound of a can opener in the vignette is an example) is repeatedly and consistently paired with a deprivation induced drive state of hunger, the neutral stimulus when presented alone will elicit the hunger state. As a result of conditioning, the environmental cues are able to elicit the drive state and, thereby, induce eating. Furthermore, Hull felt that the stimulus associated with the deprivation would motivate eating even in the absence of deprivation. A second view (Weingarten and Powley, 1977) assumes that the association of an environmental cue (i.e., restaurant) with food (rather than the drive state) is responsible for people's motivation to eat when not biologically deprived. According to this approach, food induces hunger and cues present during eating become able to elicit hunger as a conditioned response. Furthermore, the more palatable the food, the stronger the hunger and, therefore, the more intense the conditioning of hunger to the cues associated with eating.

A review of the conditioned hunger literature is presented first followed by a discussion of the palatability idea. As we will discuss, the literature investigating conditioned hunger has not been consistently positive, while the view that the association of food with an environmental event is responsible for eating in nondeprived animals and people remains to be tested. The main focus of the experiment reported here is to evaluate this view.

Conditioned hunger literature. Anderson in 1941 suggested that a drive such as hunger is originally aroused by internal conditions of the animal but that the drive could become aroused by the characteristics of the external situation (the drive becomes externalized). Anderson further argued that once the drive can be activated by the external situation, it should be possible to use the externalized drive in the learning of a maze. Thus, once the external characteristics of an environment have been associated with deprivation, these cues could motivate the learning about a new environment even in nondeprived animals. To demonstrate the conditioning of hunger, Anderson (1941) gave hungry rats 73 trials on one maze (Maze A) under normal conditions of hunger and reward to produce externalization of drive. Then in the first maze (A) one group was deprived but never rewarded, another group was satiated but received no reward. The animals were then transferred to an entirely new maze (Maze B). Control groups were run under comparable conditions on the second maze (Maze B) but had not been trained on the first maze (Maze A). The second maze (B) was a 6-unit T-maze with a pattern of choices the opposite of the first six choices of the first maze (A). It was found that the animals who had experienced deprivation in the first maze showed faster learning when compared with animals in the control group which had not received training in Maze A or experimental animals that were satiated in Maze A. Anderson assumed that the conditioning of hunger to the external characteristics of the maze (A) produced greater motivation in Maze B than was experienced by experimental satiated animals or control animals and that the greater motivation was responsible for more rapid conditioning in the second maze (B) in the conditioned hunger condition.

Calvin, Bicknell, and Sperling (1952) conducted another experiment which demonstrated the establishment of conditioned hunger. They used two groups of animals: a strong drive condition and a weak drive condition. Animals in the strong drive condition had been deprived of food for 22 hours; those in the weak drive condition had been deprived for only one hour. Both groups of animals were fed in their home cages. They were given 25gm of a food mixture and food consumption was measured after five minutes and 15 minutes. After the specified deprivation time, each animal was placed in a striped box under either strong drive or weak drive condition. After 24 conditioning days, there were four test trials during which all of the animals were presented with 50gm of the food mixture in the striped box. The test trials were scheduled so that the level of hunger would be intermediate between the two levels used during conditioning, and the following three tests were given at successive intervals of 12 hours. Measurements of food consumption were taken at the end of five minutes and 15 minutes. Results of the test trials showed that animals which had been conditioned in the strong drive state consumed more food in each of the four testing periods than animals in the weak drive state. These results indicate that when the striped box was associated with strong drive, it elicited more hunger than when associated with weak drive despite the fact that during testing deprivation levels were equivalent for both groups. Two replications of this experiment by Calvin, Bicknell, and Sperling (1952) also showed conditioning of hunger to an environment associated with strong drive.

However not all studies have reported conditioned hunger. In a review of the empirical evidence for conditioned hunger as a drive state, Cravens and Renner (1970) discovered that there were 11 articles investigating conditioned hunger with amount of food consumed as a dependent variable. They found that four of the 11 articles showed positive evidence of conditioned hunger. These four experiments discovered that greater food or water intake was produced after exposure to an environment associated with strong drive than an environment associated with weak drive. However, the other articles failed to find the conditioning of hunger. Anderson (1941) and Calvin, Bicknell, and Sperling (1952) conducted the first positive reports of conditioned hunger; other studies investigating the conditioning of hunger are described below.

Siegel and MacDonnell (1954) employed the methodology used by Calvin et al. with a few significant changes. They believed that the animals in the Calvin et al. study lost weight during the course of the experiment and were in a state of semi-starvation in the terminal stages of the experiment. To correct this problem Siegel and MacDonnell used a fixed daily feeding interval rather than providing a certain amount of food. After taking daily recordings of body weight and food intake, they found that a 20 minute feeding interval was the shortest interval which permitted normal weight gain. This 20 minute feeding interval was used throughout their experiment. Siegel and MacDonnell (1954) conducted a test of conditioned hunger after a conditioning phase of 24 days, which was the same as used by Calvin et al. (1952). Recordings of food intake were obtained after the first ten minutes and then again after 20 minutes of testing. Three additional test trials followed at 12 hour intervals. A comparison of mean intakes for the entire series of test trials revealed a non-significant difference between the strong and weak drive groups. These results do not indicate that hunger can be conditioned to environmental cues.

In contrast, Wright (1965) reported positive evidence of conditioned hunger. The procedure employed by Wright was similar to that of Calvin et al. (1952) and Siegel and MacDonnell (1954) except that each animal was placed in a distinctive box under a weak hunger condition and in a qualitatively different box under the strong hunger condition. The animals were later tested in both boxes under an intermediate level of hunger. To compensate for the fact that daily feeding necessarily followed strong-drive training and that this could be a possible factor for greater food intake, the animals were assigned to three conditions of delay of return to the home cage and food following strong-drive training: (1) immediate return to home cage and food. (2) immediate return to home cage but with food delayed, and (3) delay in a neutral box before return to home cage and food. This control procedure insured that association of deprivation and not food with the environment was responsible for the conditioned hunger effect. Following 36 days of conditioning, two tests of conditioned hunger were conducted. Wright found significantly greater intake of food in the strong-drive group. Furthermore, equivalent conditioning of hunger was found in the immediate and delayed conditions.

Wike, Cour, and Mellgren (1967) conducted three experiments to assess the reliability and generality of Wright's findings. They replicated Wright's procedure except that dry rather than liquid food was used. No evidence for conditioned hunger was found in all three experiments. They concluded that the assumption that hunger could be learned as the result of association with unconditioned drive state does not appear to be a viable assumption.

Trost and Homzie (1966) used a slightly different procedure to assess the conditioning of hunger. The weight of subjects before and after testing was employed as a measure of food intake. After 14 days of habituation to a schedule of 12 hour free feeding followed by 24 hours of deprivation, the subjects were then divided into two groups; a strong drive (SD) or a weak drive (WD) group. These groups were matched for food intake and body weight. All subjects were placed in free feeding cages for 12 hours during the 30 conditioning days. During conditioning the WD subjects were then placed in the environmental chamber for deprivation hours 0 - 12 and then removed to their home cages. The SD subjects were placed in the environmental chamber for deprivation hours 12 - 14. Testing was conducted under intermediate drive by allowing all subjects 12 hours of free feeding prior to three hours of deprivation. The subjects from each group were then weighed and placed in the environmental chamber. Stimulus conditions were the same as during conditioning except for the placement in each environmental chamber of 60gm of wet mash. Amount of food consumed after two minutes and then after five minutes was measured and the animals were again weighed before being returned to their home cages. All subjects were then allowed six hours of free feeding followed by six hours of deprivation and another testing in the same manner as described above. Results showed a significant weight gain for animals in the SD group compared to the WD group, but no significant difference in the amount of food consumed in the five minute test period. Trost and Homzie suggested that previous failures to find evidence of conditioned hunger using amount of food consumed as a measure of conditioned hunger could be attributed to insensitivity of the measurement rather than the absence of conditioning. Amount consumed could be an insensitive measure because of the amount of food wasted (e.g., the food which dropped through the sides or bottom of the cage as opposed to actually consumed can not be assessed).

Unfortunately, in an experiment incorporating the use of body weight as the index of conditioning of hunger, Cravens and Renner (1970) failed to find positive evidence for conditioned hunger using amount of food consumed rather than weight of the animals before and after eating. In a second experiment they found a significant reversal of conditioned hunger with animals eating more in a weak drive associated stimuli situation using similar procedures.

Another experiment failing to find evidence of conditioned hunger was conducted by Myers and Miller (1954). They employed the acquisition of a new response as the measure of conditioned hunger. In their study, four groups of animals were given only one hour access to food each day. The animals were equated for mean body weight and were given 70 trials, 30 trials, ten trials, or 0 trials of drive acquisition training prior to the establishment of a door touching response which resulted in a food reward. It was assumed that those animals with a greater number of learning trials (one per day for each group) would acquire a new response of bar pressing without the primary drive of hunger more rapidly than the other groups. Myers and Miller (1954) reported that all four groups showed equivalent acquisition of the bar press response. These results show that the number of trials under deprivation did not affect the learning of a new response and demonstrate no evidence for conditioned hunger.

Howard and Young (1962) also reported no evidence of the conditioning of hunger. They exposed three groups of monkeys to a flashing light for a period of 30 minutes once a day for 47 days. All animals were on a 23 1/2 hour deprivation schedule. The drive group received the CS prior to feeding, the incentive group during feeding, and the control group after feeding. Subsequent testing of the animals under satiation failed to produce significant differences between the groups in terms of either the rate of response of a previously learned response or progress in learning of a new instrumental response.

In an elaboration of Anderson's 1941 study, which was discussed earlier, Wike and Knutson (1966) and Cravens and Renner (1970) failed to find conditioned hunger. They attempted to show that if conditioning has taken place, subjects will, when given a choice between a stimulus associated with a strong drive and a stimulus associated with a weak drive, show a tendency to approach stimuli associated with a weak drive rather than strong drive, as well as avoiding events associated with a strong drive state.

Wike and Knutson (1966) conducted two conditioned hunger experiments observing the running speed of subjects toward and away from a test box. Their animals had been exposed to the box under either strong drive condition or weak drive condition. They performed two additional experiments to observe whether subjects preferred a box previously associated with a weak hunger or a box previously associated with a strong hunger. In their studies all subjects were deprived for 23 hours and then put in a one goal box for 30 minutes. They were then returned to their home cages, left for 30 minutes and then fed for one hour. After 30 more minutes without food they were put into the other goal box for 30 minutes. Half the subjects were put in the black goal box while deprived, then the white goal box while satiated; the other half had reversed goal boxes. No significant differences were found among the groups in any of the experiments. These results indicate no differential association of environments present during low or high drive.

Cravens and Renner (1970) gave animals a daily choice in a preference situation between stimuli associated with strong drive and weak drive. In 120 trials subjects did not develop a preference for one set of stimuli over the other. Again, Cravens and Renner's results indicate no differential conditioning of hunger to environments associated with strong or weak hunger drive.

Cravens and Renner (1970) in their review reported that in only five of 20 articles investigating conditioned hunger reported positive results. They assume that since the likelihood that positive findings will be reported as opposed to negative findings, the evidence leans heavily against the validity of the conditioned hunger phenomenon.

All of the experiments cited by Cravens and Renner that have attempted to condition hunger have used external visual or auditory CSs. Seligman (1970) suggested that animals have inherited biological systems which allow them to make certain associations more easily than others.

Mineka (1975) conducted a series of experiments to test the idea that salience affects the conditioning of hunger. Her first experiment was similar to the one conducted by Wright (1965) and used external color cues as CSs for different levels of hunger drive. Mineka found that subjects did not eat more in the strong drive condition than they did in the weak drive condition. Also, the latencies to eat were not significantly different between high and low drive treatment. These results are identical to those reported by Wright. A second experiment examined the possibility of conditioning hunger using the same paradigm as in Experiment 1 but with distinctive flavors rather than external color cues as CSs for the different hunger levels. In Experiment 2a, one group of subjects received peppermint as its strong drive flavor and lemon extract as the weak drive flavor. Nineteen hours of deprivation served as high drive and one hour as low drive in this study. A second group received peppermint as the weak drive CS and lemon extract as the strong drive CS. The first test was administered 18 days after conditioning and these results indicated that subjects ate significantly more after the strong drive taste was administered than after the weak drive taste. Furthermore, either peppermint or lemon could serve as a strong drive taste CS. After a reconditioning day a second test was administered followed by another reconditioning day and then a third test. The second and third tests revealed that conditioning had extinguished. Latencies to eat did not differ significantly in any of the three tests.

Mineka (1975) used maple and orange as taste cues in Experiment 2b and the same conditioning method was employed as used in Experiment 2a. Subjects having orange flavor as their strong drive CS ate more after the strong drive presentation. However the use of maple as the strong drive CS did not produce a significant difference in amount consumed when compared with maple used as the weak drive CS. Tests two and three again revealed no significant differences for either group. The results from Experiment 2a show that taste cues can be conditioned to motivate eating and therefore support the view that tastes serve as better CSs for different levels of hunger drives than do external color cues. The failure of maple to become associated with high drive in Experiment 2b could reflect the lack of salience of maple flavor. Flavors do differ in ability to be associated with illness on the strength of their association with deficiency in diet (Rozin and Kalat, 1970); therefore it is not surprising that taste cues differ in their ability to be associated with hunger. The results of Experiments 2a and 2b support the conclusion that tastes can be effective CSs in the conditioning of hunger. However, a third study by Mineka failed to replicate the initial success of Experiments 2a and 2b. This third study added a control group to assess whether a strong drive CS increased the amount eaten above an appropriate baseline and whether a weak drive CS decreased the amount eaten below an appropriate baseline. There was no evidence for the discriminative conditioning of hunger although there was some evidence in the third study for the conditioning of hunger to the whole conditioning situation. The control groups which had only been in the conditioning situation under a weak drive CS (three hour deprivation) did eat less than the experimental groups which had been in the conditioning situation under both high and low degrees of hunger.

Cravens and Renner (1970) proposed that the slowness of onset of hunger could explain the difficulty in obtaining positive evidence for conditioned hunger. If the assumption of slow onset is correct, then conditioning should be stronger with rapid induction of drives. However experimental attempts to condition hunger and thirst by rapidly inducing drives have yielded negative results. For example, Andersson and Larsson (1956) failed to condition thirst in goats using rapid onset of thirst via hypothalamic brain stimulation as the UCS, while Huston and Brozek (1972) were unable to condition hunger elicited by lateral hypothalamic brain stimulation. These results do not indicate that the slow onset of hunger is responsible for failure to produce reliable conditioned hunger.

<u>The association of food and environmental events</u>. Hunger has been defined as an internal state which motivates an animal to search for, accept, and eat foods. It is generally associated with a state of deprivation and food is the reinforcer which reduces this need state. However the level of deprivation at the start of a meal is not a determinant of meal size. Although the internal stimulus to eat (hunger) is a critical and necessary factor for the initiation of feeding, LeMagnen (1971) found that the differences in amount consumed are determined by

the palatability of food; the greater the palatability of food, the more food consumed regardless of the level of deprivation. At the beginning of a meal, therefore, it is not how long an animal has been deprived of food which determines how much he will eat, but rather the taste and texture of the food and how pleasing it is to the animal once eating has been initiated.

Corbit and Stellar (1964) demonstrated that an animal's food intake is directly related to the palatability of its diet. Their animals were given ad lib access to a series of diets in the following order: Purina laboratory chow powder, Purina laboratory chow pellets, a high-fat diet consisting of 33% (by weight) vegetable fat (Crisco) and 67% Purina laboratory chow powder, and finally a mineral oil diet consisting of a mixture of 1.0gm liquid vegetable fat (Crisco oil) per 1.58gm mineral oil, producing a caloric density equal to that of the laboratory chow; then 35mls of this mixture were added to 100gm of Purina laboratory chow powder, yielding a diet with a texture similar to that of the high-fat diet. Animals given the high-fat diet period showed a significant increase in body weight and reduced their caloric intakes when given laboratory pellets for a second time with most animals eating little or nothing the first day of this period. When given the mineral-oil diet the caloric intakes of all animals increased with body weights reaching the high-fat diet levels. However, the rate of weight gain on the mineral-oil diet was lower than that on the high-fat diet. Corbit and Stellar concluded that the stimulus properties (palatability) of a diet can determine how much an animal eats and the level at which it regulates it's body weight. Although the laboratory chow pellets and the high-fat diet also had different caloric densities, the mineral-oil diet had a caloric density equal to the laboratory chow and stimulus properties similar to the high-fat diet. The fact that all animals increased their food intakes on the mineral-oil diet and gained weight to reach the high-fat level suggests that the palatability of the food rather than caloric value determines level of food intake. The importance of oral factors was also demonstrated by experiments in which food was delivered directly to an animal's stomach bypassing the oral receptors (Snowden, 1969). The animal was trained to press a bar to deliver food and although hunger did cause the animals to eventually learn to press the bar to initiate feeding, the amounts eaten were small.

Teitelbaum (1971) performed a series of four experiments to investigate the role of stimulus factors in the diet in regulating food intake. The experiments tested the effects of caloric dilution, texture, and positive and negative qualities of the diet. He found that when a standard diet of powdered Purina chow was adulterated with non-nutritive cellulose, the normal animals increase their intake up to a 25% dilution. The stimulus variation of the standard diet showed that: (a) change in texture (grinding pellets to powder) does not affect normal animals, (b) negative taste (1.125% quinine) does not affect normal animals, and (c) positive taste (50% dextrose) causes normal animals to decrease their intake of the dextrose diet, thus appearing to respond to the caloric value of the diet. Teitelbaum (1971) concluded that normal animals seem to eat for calories and tend to ignore stimulus characteristics of diet.

Young (1949) proposes a theory of food acceptance based upon the assumption that rats accept foods which they like, that foods differ in the degree to which they arouse an immediate positive affect. Young feels that rats run faster in approaching a highly palatable food and accept it more promply than in approaching a less palatable food. Although this view is different from the view that animals accept foods which they need to maintain homeostasis and to survive, Young states that available results show that animals like foods which they need.

Although deprivation does not control amount consumed, the initiation of eating behavior is determined by hunger level. When the animal starts to eat, the size of the animal's meal is directly related to the intensity of the cephalic response evoked by the food. Powley (1977) described the responses which occur when an animal is exposed to food as an example of a cephalic reflex (cephalic reflex is a reflex which originates in the head region, output goes to the automonic nervous system and the endrocine system controlling secretion, absorption and motility of the gastrointestinal tract and mediated by the CNS). These internal responses elicited by sensory contact with food rather than by postingestional consequences of food, serve to prepare the animal to digest, metabolize, and store ingested food. They are elicited by the taste and smell of food and include the secretion of saliva, gastric juices, pancreatic enzymes, and insulin. The cephalic responses are a series of fast phasic responses in energy metabolism made upon contact with food or food cues. Thus, the mouth-watering sensation one feels when smelling a pie baking is part of the cephalic response to food (Rolls, Burton, and Mora, 1976). An animal's motivation to eat intensifies during eating because the cephalic responses elicited by food stimulate the lateral hypothalamus (LH) feeding center and maintain eating to satiety. This cephalic reflex can be conditioned by environmental stimulation associated with either palatable foods or stimulation of the LH. A study by Weingarten and Powley (1977) found that a light-and-tone CS, when paired with a high fat food, was capable of producing a CR of the secretion of a gastric acid. A CS paired with LH stimulation was observed by Booth, Coons, and Miller (1969) to produce a decreased blood glucose level. Stimulation of the LH area was also observed to initiate the cephalic reflexes (Anand, Chhina, and Singh, 1962). These reflexes maintain activation of the LH area and cause the animal to continue eating.

The cephalic reflex concept of eating behavior explains why the animal initiates feeding behavior and continues to eat but does not explain what motivates the instrumental behavior exhibited in food seeking. Conditioning of the cephalic response rather than deprivation probably is responsible for food seeking behavior.

Spence (1956) proposed a hypothetical view of the process which motivates appetitive behavior. According to Spence the first few associations of environmental cues with reward produce a conditioned or anticipatory goal response (rg). This conditioned goal response produces the internal stimulus changes which motivate an animal to approach a rewarding goal. With repeated associations the environmental cues become more capable of producing the anticipatory goal response. The anticipatory goal response has the same characteristics as the cephalic response in that both motivate appetitive eating behavior.

Other psychologists have suggested similar hypothetical models of appetitive behavior. Bindra (1974) proposed a motivational state specific to eating behavior. He suggested that the central representation of the visual/olfactory properties of food activate the sensory-motor coordination of instrumental approach acts. Once the animal has come into contact with food, this central representation activates the consummatory act of eating. The central representation of certain properties of food (e.g., taste, texture) is combined with the influence of organismic-state features (e.g., low blood sugar level) to produce a central motive eating state. The central motive eating state has a general excitatory influence on those sensory-motor coordinations which are typically involved in appetitive behavior. It also directly activates certain regulatory mechanisms to produce viscerosomatic reactions such as salivation. In a circular fashion the central representation of food, which provided the incentive required for the activation of the central motive state, is itself excited further by the specific central motive state. This circular enhancement results in the arousal of the sensory-motor coordinations of instrumental acts. The anticipation of food is central to Bindra's model. No overt response is required to produce incentive motivation. The animal responds to the environmental stimulus associated with food as if it were food (Brown & Jenkins, 1968). The central motive state makes the environmental stimulus so powerful that the animal acts in response to it rather than to any other stimulus. This is similar to the cephalic response in that Bindra's incentive motivation is like the preparatory responses elicited by the cues associated with food. Both the cephalic response and the central motive state result from exposure to food and both initiate food seeking behavior.

The purpose of the present study is to determine whether or not the conditioned cephalic reflex motivates eating. During this study it will be determined if environmental cues associated with different qualities of food motivate differences in appetitive behavior in the absence of food. It is hypothesized that differences in palatability of food will produce differences in the strength of the conditioned cephalic response and, therefore, in latencies in approaching and initiation of eating behavior.

METHOD

Subjects. The subjects were 28 naive albino female rats purchased from Sprague-Dawley (Madison, Wisconsin). The rats were approximately 75 days old and weighed approximately 200g at the start of the experiment. They were received in the laboratory ten days prior to the start of this experiment and were individually housed. They were maintained on ad lib food and water until the start of the experiment.

Apparatus. The testing apparatus was a T-maze 28 inches long with 12 inch long arms. The T-maze was five inches wide and five inches deep. There were hinged plexiglas tops on the stem and the arms. The floor was quarter inch hardware cloth.

One arm was painted black on the inside and separated from the body of the T by a black plexiglas barrier. The other arm was painted white on the inside and separated by a white plexiglas barrier. The barriers were guillotine doors. The walls and frame of the T-maze were made of plywood and with the exception of the specified painted areas were unpainted. There were two T-mazes used for conditioning and testing. They were placed side by side on a black topped table in a bare room five feet by nine feet.

Procedure - Pretraining Phase. Each subject was placed on food deprivation for 15 days of pretraining prior to the conditioning phase of the experiment. On each of the first 12 days, the subjects were presented with 20g of one of the three foods to be used in the conditioning and test phases of the experiment. On day one all subjects were given 20g of powdered chow mixed with 1/2g sugar and 1g water. On day two all subjects were given 20g of Purina moist and chunky dog food. On day three all subjects were given 20g of Gravy Train canned dog food. The specified food was presented to the subjects in a glass feeding dish in their home cages. This sequence of food presentations was repeated three times over the next nine days.

On days seven through 12 of the pretraining phase, the amount of conditioning food consumed by each subject was recorded to determine food preference. It was found that 26 of the 28 animals preferred the canned dog food over the sweetened powdered chow and that the powdered chow was preferred over the moist and chunky. The subjects were returned to ad lib food (regular rat chow) following the first 12 days of the pretraining phase. For days 13 - 15, the subjects were given 2 1/2g of one of the three conditioning foods in addition to ad lib chow. After five minutes the amount of the conditioning food consumed was recorded and the conditioning food removed from the home cage. The preference order was the same as before: canned dog food, powdered chow, moist and chunky.

Conditioning Phase. Beginning on day 15 the subjects were randomly divided into four groups. These groups differed in terms of the food used in the start box for the conditioning phase of the experiment. All subjects were given 20g of regular rat chow in their home cages daily.

Subjects in the powdered chow (PC) group (n=7) were placed in the stem end of the T-maze. This was designated as the start box. They were presented 2 1/2g of powdered chow mixed with 1g water and 1/2g sugar. Subjects in the moist and chunky (MC) group (n=7) were placed in the start box and presented 1 1/2g of moist and chunky food. Subjects in the canned food (CF) group (n=7) were placed in the start box and presented 2 1/2g of canned dog food. Subjects in the control (CO) group (n=7) were placed in the start box with no food.

For each of the groups, after five minutes, the experimenter lifted the barriers to the arms of the T-maze.

Subjects were left in the start box for five minutes because it was felt that a shorter period of time would be optimally conducive to conditioning while longer than five minutes might lead to satiety and therefore no motivation to seek more food. The black arm was designated as the goal box. If the subject entered the black goal box she was given 2 1/2g of the least preferred of the conditioning foods (the moist and chunky). The least preferred conditioning food was determined by the amounts consumed during pretesting. Subjects were allowed to remain in the goal box for five minutes before being returned to their home cages. If the subject entered the white arm of the T-maze, she was immediately returned to her home cage. If the subject did not enter either arm within five minutes, she was returned to her home cage without being given any additional food.

To vary the order of presentation for conditioning, the sequence of subjects one through 28 was used on day one of conditioning. On day two of conditioning the sequence of subjects was 28 through one. The sequence was alternated for each of the conditioning days. On test days the sequence of one through 28 was always used. Four experimenters were used throughout the experiment for conditioning and testing with two working each day.

Testing Phase. Following an initial conditioning phase of eight days, testing was conducted after four conditioning days in each of the final four weeks of the experiment. (The first test took place after a total of eight conditioning days.) On each test day the subjects were placed in the start box with no food presented. They were left for five minutes in the start box. The barriers were then lifted and the subjects were allowed to go into either the black or white arm of the T-maze. If they went into the black goal box they were given 2 1/2g of moist and chunky food and allowed to remain for five minutes. If they went into the white arm or did not enter either arm within five minutes they were immediately returned to their home cages.

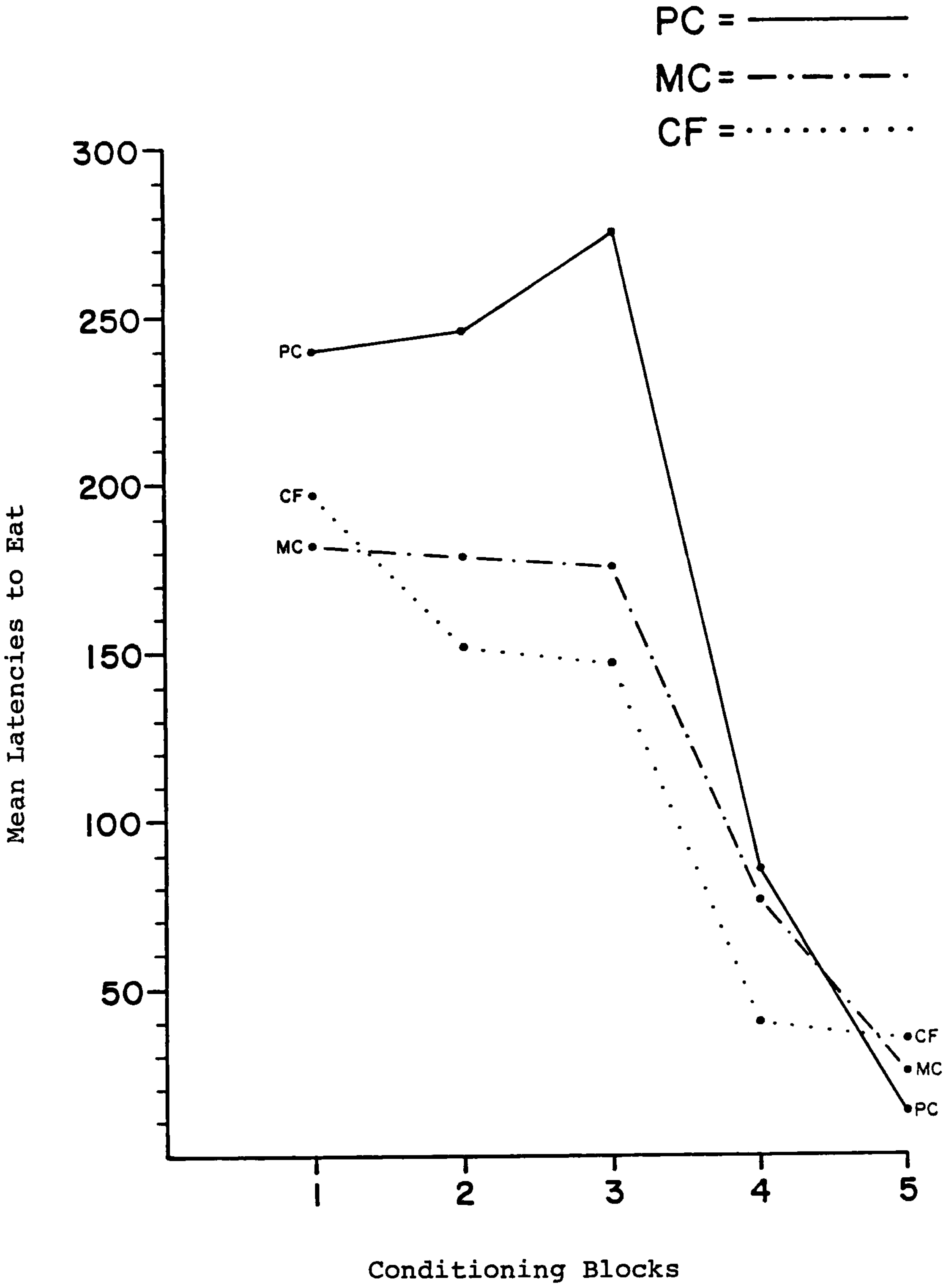
On each of the conditioning days, the latency to eat and the amount of food consumed in the start box was recorded for the subjects in the PC, MC and CF groups. Subjects in the control group were given no food in the start box. For the subjects in all groups, recordings were made of the latency to enter the black arm, latency to eat in the black arm, amount consumed in the black arm, and number of entries into the white arm. Latencies were determined with the use of a stopwatch.

A groups by repeated measures analysis of variance was employed to compare the results of treatments and days ($p<.05$ used throughout). For those subjects not entering the black arm and therefore with no measurement of latency to eat or amount consumed in the black arm, the average score of the other subjects in their respective groups was used. Duncan's multiple comparisons (Edwards, 1950) were employed to compare the differences in treatment. A one-way analysis of variance was employed to determine food preference seen in the pretraining phase ($p<.05$ was used).

RESULTS

An analysis of variance was performed on the amount of the three foods consumed to test food preferences, which yielded a significant difference in food intake, $F(2,87)=31.06, p<.01$. The subjects ate most of the canned food, followed by the powdered chow, and least of the moist and chunky food. The mean intakes for the three foods were CF 1.59, PC 1.04 and MC .14.

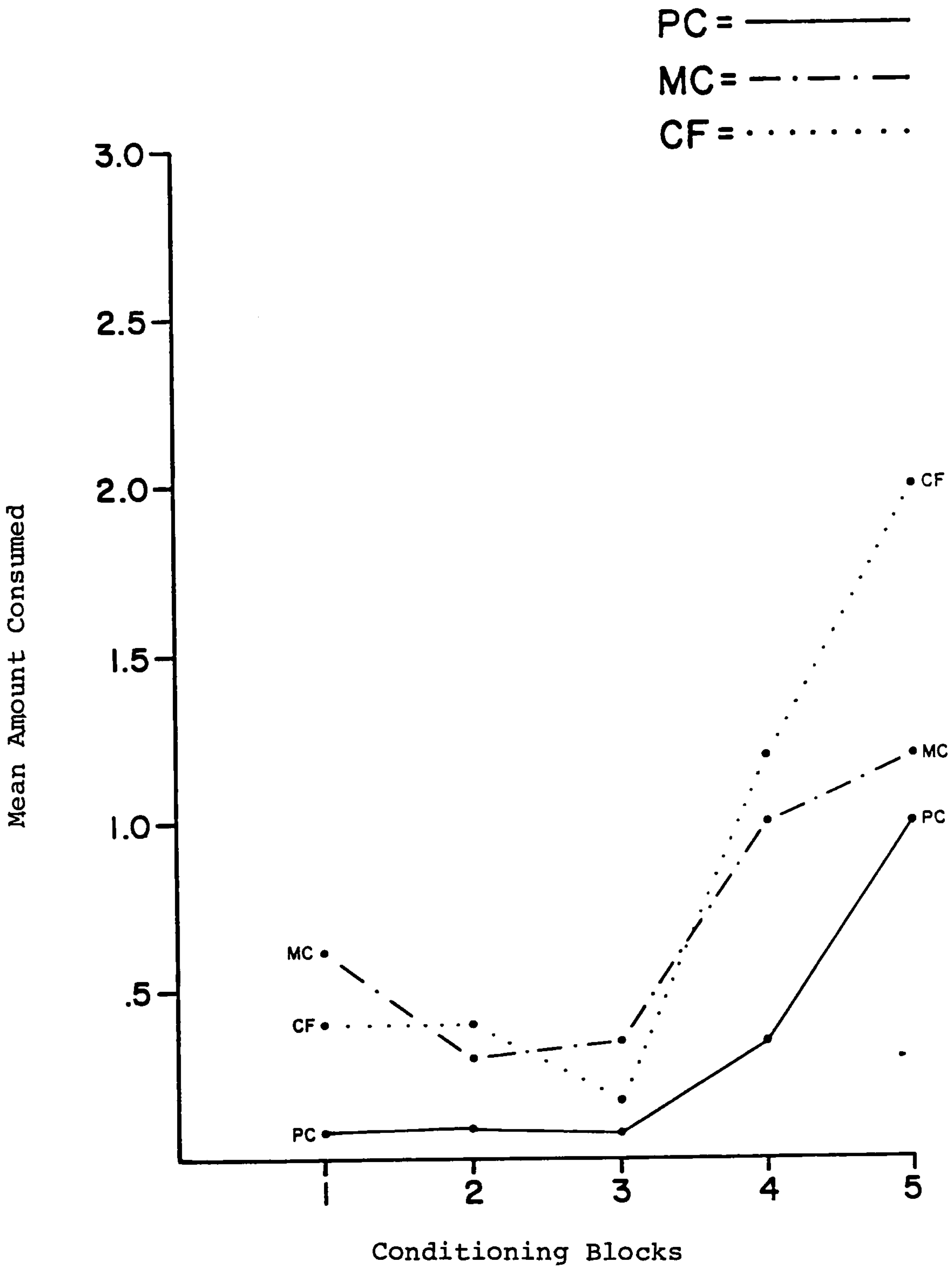
Over the period of conditioning days all groups showed a decreased latency to eat in the start box. The CF animals exhibited the fastest decrease in response latency while the PC animals exhibited the slowest decline in latency to eat. Figure 1 presents the mean latency to eat over the five conditioning blocks (four days per block) for the three treatment groups. A three (Treatments) by five (Days) analysis of variance yielded a nonsignificant Treatments effect, $F(5,72)=2.46$,ns, a significant Days effect, $F(4,72)=93.04, p<.01$, and a significant Treatments by Days interaction, $F(5,72)=3.75$, $p<.05$. Duncan's multiple comparisons showed that the PC group took significantly longer to begin eating than the MC or CF groups. This occurred over the first three blocks of conditioning days. By the fourth block


PC =
MC =
CF =
300
250
200
150
100
50
Mean Latencies to Eat
PC
CF
MC
CF
MC
PC
1
2
3
4
5
Conditioning Blocks

the PC group took significantly longer than only the CF group and by block five of conditioning days, differences between the three groups were no longer significant. All three groups significantly decreased latency to eat in the start box between conditioning block one and five.

Conditioning data showed that the amount consumed in the start box increased for all three treatment groups (See Figure 2). Also, the CF animals showed the fastest increase in amount consumed and the PC animals exhibited the slowest increase in amount consumed. A three (Treatments) by four (Days) analysis of variance yielded a significant Treatments effect, $F(2,72)=3.97, p<.05$, a significant Days effect, $F(4,72)=690.87, p<.01$, and a significant Treatments by Days interaction, $F(8,72)=25.99$, $p<.01$. Multiple comparisons of the data showed that all groups increased the amount consumed significantly over blocks four and five of conditioning. Also, for the first three blocks of conditioning days there were no significant increases in amount consumed among the groups, although the MC and CF groups did consume significantly more than the PC group.

Examination of the mean latencies to enter the black arm of the T-maze during conditioning did not show a significant change. Figure 3 shows the results from the three treatment groups and the control group. A four (Treatments) by four (Days) analysis of variance yielded a nonsignificant Treatments effect, $F(3,72)=2.39$, ns,


PC = ———
MC = — · — · —
CF = · · · · · ·
3.0
2.5
2.0
1.5
1.0
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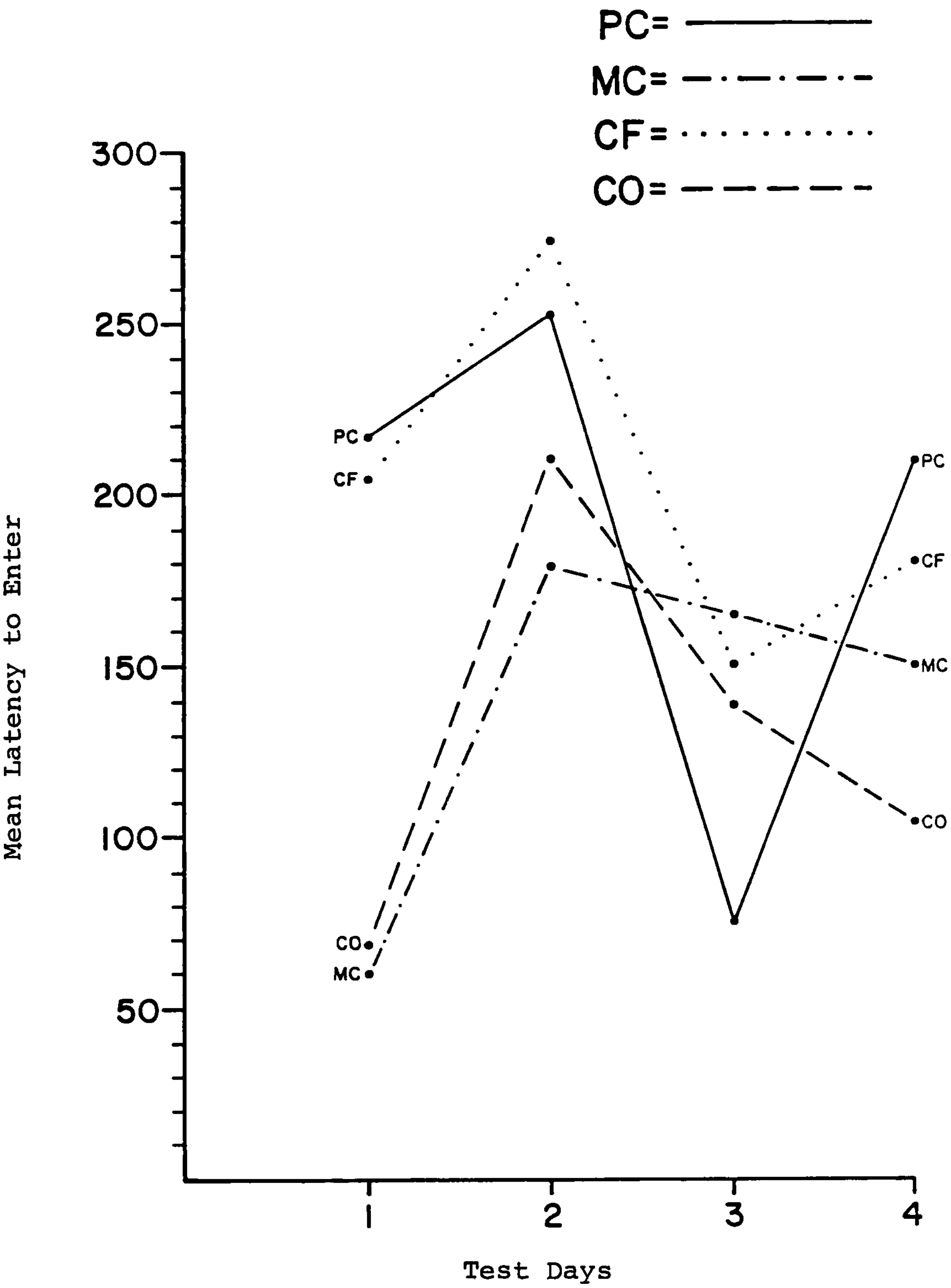
Mean Amount Consumed
MC
CF
PC
CF
MC
PC
1
2
3
4
5
Conditioning Blocks


PC=
MC=
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CO=
300
250
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150
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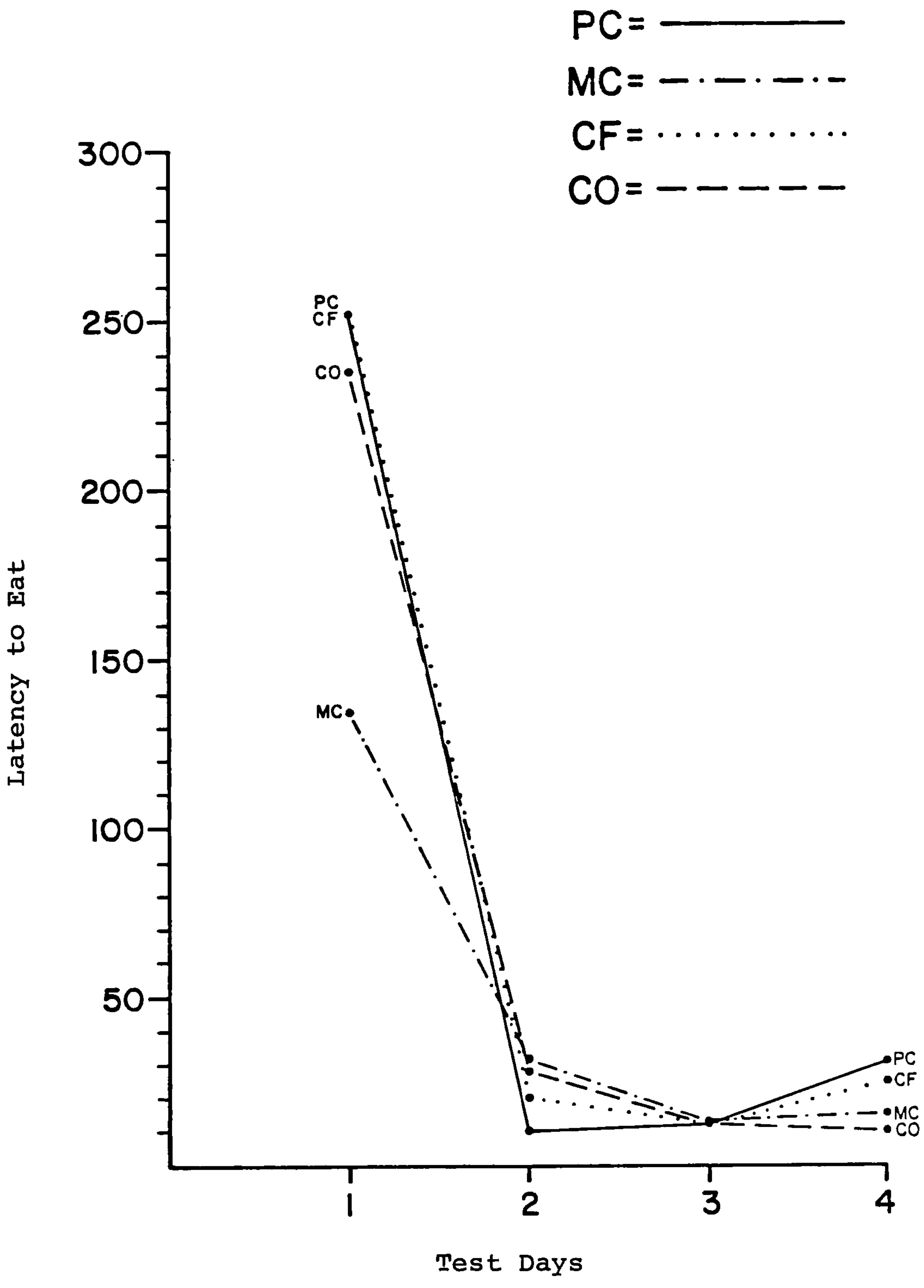
50
Mean Latency to Enter
1
2
3
4
Test Days
PC
CF
CO
MC
PC
CF
MC
CO

a significant Days effect, F(3,72)=4.31,$p<.05$, and a nonsignificant Treatments by Days interaction, F(9,72)= 1.08,ns. Although there was a significant Days effect, inspection of Figure 3 does not show any consistent pattern of response latency to enter the black arm of the T-maze. A total of five animals did not enter either arm of the T-maze on test days. Three of these animals were from the CF group with one from each of the other two treatment groups. All animals from the control group entered on of the arms of the T-maze.

There was a significant decrease in the latency to eat in the black arm of the T-maze for all treatment conditions over four test days. Figure 4 presents means for the four groups of latency to eat on test days. A four (Treatments) by four (Days) analysis of variance yielded a nonsignificant Treatments effect, F(3,20)= 1.06,ns, a significant Days effect, F(3,20)=74.95, $p<.01$, and a nonsignificant Treatments by Days interaction, F(9,20)=2.16,ns. Multiple comparisons of the data showed that there were significant decreases in latency to eat between test day one and the remaining test days for all groups. Furthermore, while MC animals ate less rapidly on the first test day than the other three groups, the groups showed equivalent latencies to eat over the last three test days. On the fourth test day, animals in the control group showed a shorter latency to eat than any of the three treatment groups.


PC=
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250
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Latency to Eat
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MC
PC
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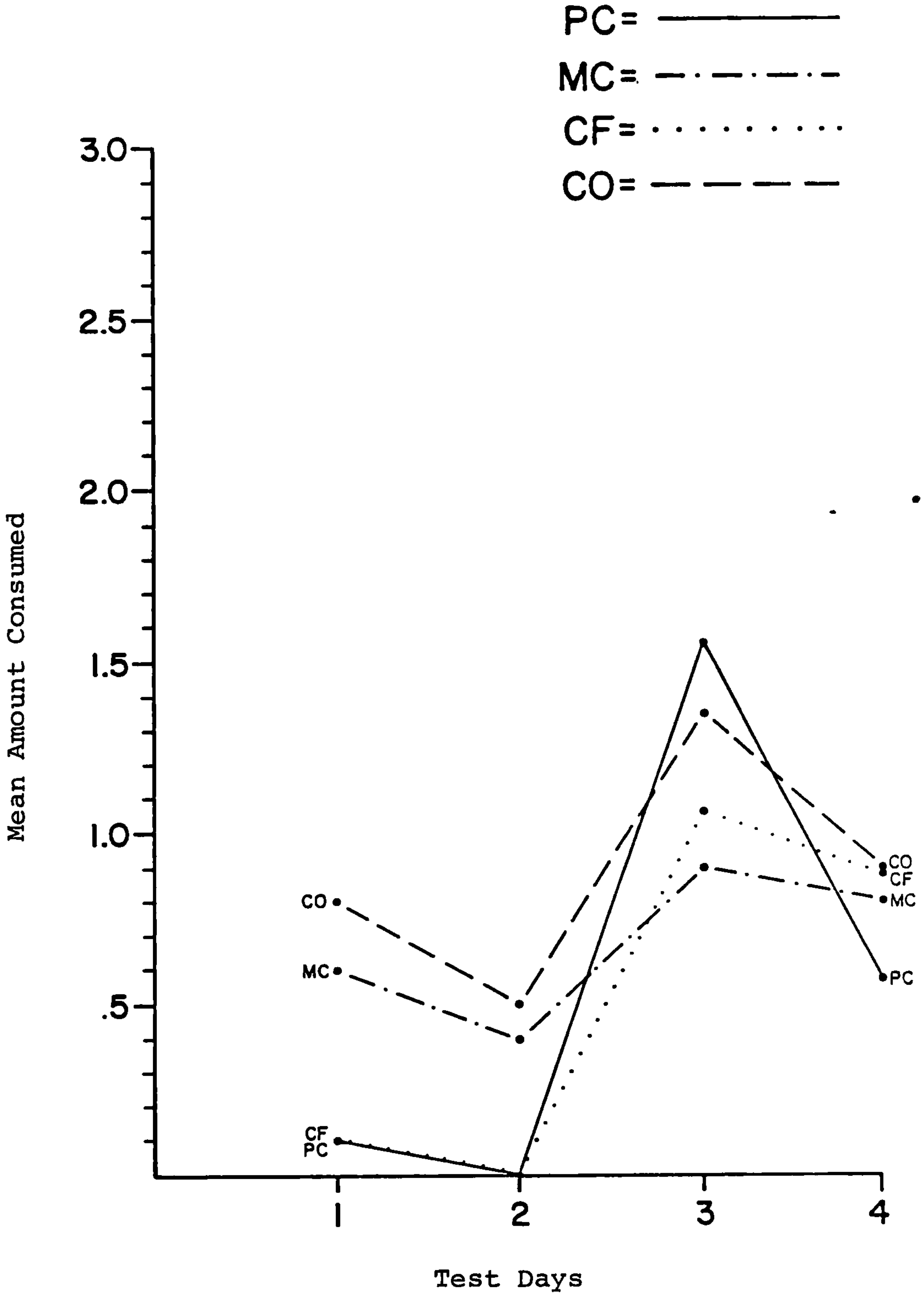
4
Test Days

Using the moist and chunky food, which was the least preferred in pretraining tests as the goal reward, all animals showed a significant increase in the amount consumed in the black arm of the T-maze during the four test days. Figure 5 presents the mean amounts consumed in the black arm during testing. A four (Treatments) by four (Days) analysis of variance yielded a significant Treatment effect, $F(3,20)=4.15, p<.05$, a significant Days effect, $F(3,20)=285.05, p<.01$, but a nonsignificant Treatments by Days interaction, $F(9,20)=.79$, ns. Multiple comparisons of the data showed that all animals ate significantly more on test days three and four than days one and two.

There were no significant differences in the animals entries into the white arm during conditioning. Figure 6 shows the number of entries by each group on the four test days.

DISCUSSION

This study evaluated the conditioning of hunger when an external cue was paired with foods of differing palatability. Three different foods were used. It was assumed that the more palatable the food, the greater the cephalic response, and therefore the higher the level of conditioned hunger. Three groups of animals were exposed to food (differing in palatability) in the start box. A control group was exposed to no food in the start box.


PC=
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Mean Amount Consumed
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1
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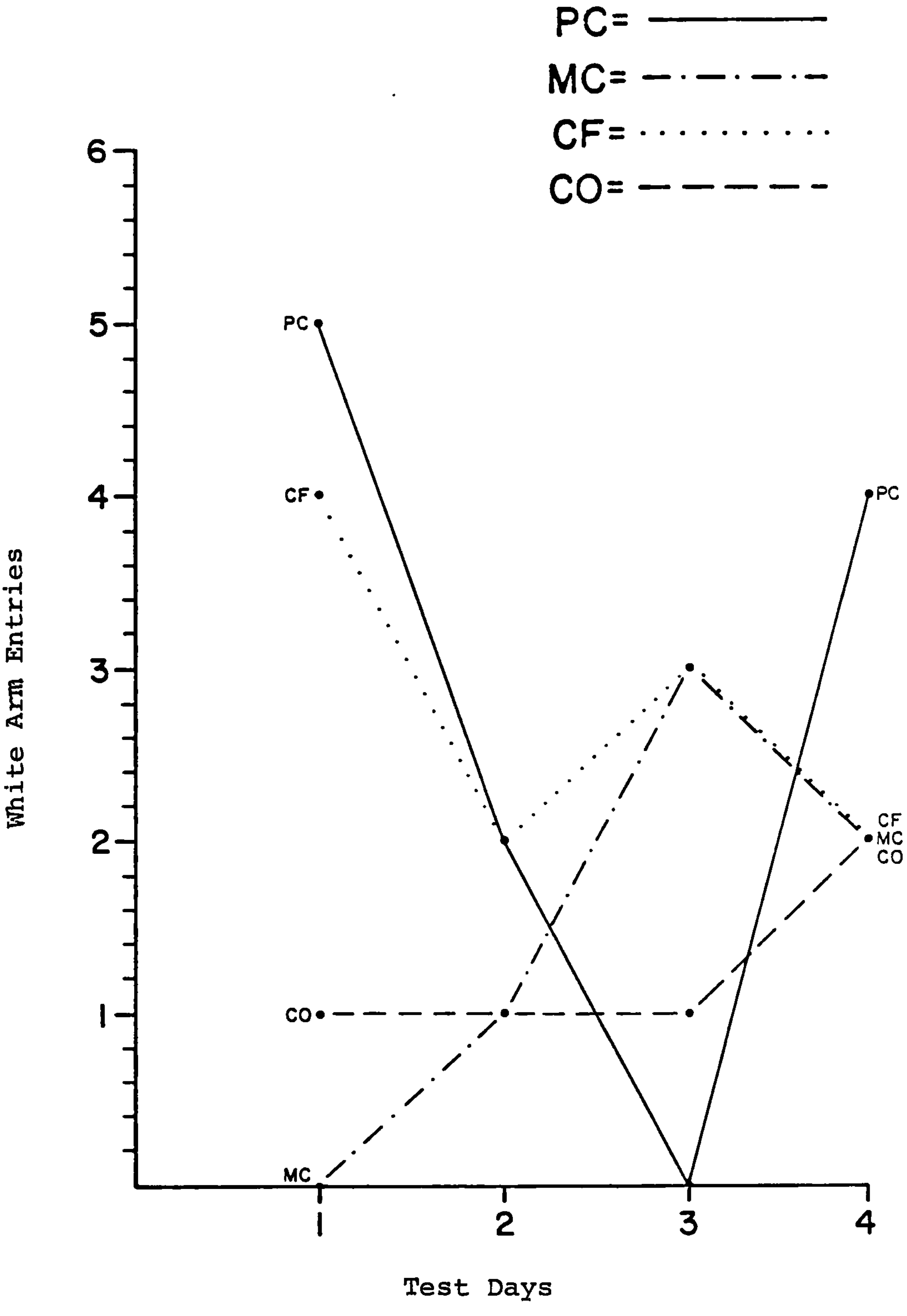
4
Test Days


PC=
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CO=
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5
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PC
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MC
PC
CF
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1
2
3
4
White Arm Entries
Test Days

Results demonstrated that the foods differed in palatability in pretraining with the animals consuming more of the canned dog food than the powdered chow, and more of the powdered chow than the moist and chunky dog food. The results also showed that the animals learned to eat rapidly and to eat a lot of food in the start box during conditioning, as well as learning to run to the black arm of the T-maze rapidly to obtain more food. Over the first three blocks of conditioning days there were no significant differences in the amounts of food consumed. Over the fourth and fifth blocks all animals increased the amount consumed with the CF group showing the greatest increase. This observation is consistent with the literature that the more palatable a food the greater amount consumed. Booth (1972) observed that with experience, animals learn to eat more of a less palatable food. It is expected that over a more extended period of conditioning days this would have occurred as all animals were beginning to eat more rapidly.

There were no differences in latency to enter the black arm of the T-maze or in amount consumed in black arm during testing (when the food in the start box was removed for all subjects). These observations indicated that hunger was not conditioned to the external cue associated with food and that the differences in palatability of foods did not affect the latencies to enter the black arm, the latencies to eat, or the amounts of food consumed on test days. All groups learned to eat significantly more rapidly in the black arm over the test days with no significant differences in the groups. Although there were significant differences in the palatability of foods used, perhaps none were of a palatable level sufficient to motivate feeding behavior. The fact that the control group initiated eating as rapidly and ate as much negated conditioned hunger.

Hull (1943) suggested that environmental stimuli associated with deprivation could acquire the ability to produce conditioned hunger. Furthermore, Hull felt the stimulus associated with deprivation would motivate eating even in the absence of deprivation. His views led to numerous studies of conditioned hunger. Although some studies (i.e., Anderson, 1941; and Calvin, Bicknell, and Sperling, 1952) did provide evidence for conditioned hunger, others (i.e., Siegel and MacDonnell, 1954; and Wike, Cour, and Mellgren, 1967) attempted to replicate these results without success. Cravens and Renner (1970) reviewed the empirical evidence for a conditioned drive state and found that in only five of 20 tests were there positive demonstrations of conditioned hunger.

LeMagnen (1971) found that regardless of the level of deprivation, the amount of food consumed depended on the palatability of the food. Corbit and Stellar (1964) also concluded that the palatability of a food can determine how much an animal eats. Although the animals in this study did eat more of the most palatable food in the start box, there was no conditioning of the palatability cues to the environmental cues so that they ate more in the black arm. Therefore, there was no conditioned hunger.

Several explanations were suggested for the inability to produce conditioned hunger. Seligman (1970) proposed that animals were not predisposed to associate environmental cues with hunger and therefore hunger would be difficult to condition to an environmental cue. A number of experiments were conducted by Mineka (1975) to test the idea that salience affects the conditioning of hunger. Mineka evaluated a salience view by pairing either an environmental cue or a taste cue with deprivation. Although Mineka reported mixed results in her experiments conditioning hunger to taste she did not find that hunger was reliably more conditionable to taste than to an environmental cue. This study did not demonstrate that the association of a food (taste) with an environmental cue produced conditioned hunger.

Powley (1977) described the responses which occur when an animal is exposed to food, including saliva, gastric juice and insulin. These responses to food are a cephalic reflex because of the involvement of the lateral hypothalamus feeding center. This cephalic reflex was shown to be conditionable by either environmental cues or stimulation of the LH area. In a circular fashion, eating causes continued activation of the LH area and causes an animal to continue eating. Although this view explains what motivates an animal to eat, it does not explain what motivates the instrumental behavior exhibited in seeking food. Hypothetical views of this process were proposed by Spence (1956) as an anticipatory goal response and by Bindra (1974) as a central motive eating state. Each of these views assumes that environmental stimuli become associated with food and that their presence motivates an animal to seek food. The cephalic reflex did not appear to be conditioned, and if foods of different levels of palatability cause different levels of intensity in the cephalic reflex, this was not demonstrated. There were no significant differences in the continuation of eating as a result of the food in the start box. Animals in the control group approached food, began eating and consumed as much as animals in the treatment groups. If all animals had been allowed to remain in the black arm for an unlimited period of time and with an unlimited amount of food, different results might have appeared.

It is also suggested that one reason for the lack of significant evidence for conditioned hunger is that external cues do not have a powerful effect on normal animals due to their internal regulatory mechanisms. Research with VMH lesions in animals suggests that the reason they eat more is the exaggeration of the cephalic reflexes of digestion and that the amplitudes of the cephalic reflexes are known to be a function of the sensory aspects of food. In tests with very palatable foods, VMH lesioned animals eat considerably more of a high-fat diet than do controls (Corbit and Stellar, 1958). The VMH lesioned animal also typically overresponds to negative taste aspects of a diet with less eating and a subsequent weight loss.

The inconsistency of positive evidence for conditioned hunger found in the literature and the results of this study suggest some directions for future research. More extensive concern for methodological issues is necessary. The use of the weight of an animal before and after consumption of food as a dependent variable has not consistently been shown to be more reliable than amount of food consumed. However a combination of both measurements might prove valuable. Moll (1959) has suggested that the rate of consumption may be more sensitive than the amount consumed in a limited time interval. The reliability of the amount consumed as a dependent variable needs to be further investigated as to whether or not it is stable from one occasion to the next. Perhaps the animals were not left in the start box or black arm long enough. Although salience of the external stimulus of taste has been evaluated, this external stimulus acts in relation to an internal stimulus to eat (hunger). The scanning of external cues does not appear to produce hunger in a non-hungry animal. A method must be defined to distinguish between feelings of hunger which are internal and do not require external cues to motivate food seeking, and food seeking behavior in the absence of hunger.

The failure of producing differences in conditioned hunger with foods of differing palatability demonstrated in this study further points to the elusiveness of the phenomenon. Perhaps normal satiated animals are not conditionable to hunger. Control of the external environment must be structured so that the potentiality for incompatible behavior does not exist. Shrouding of the testing apparatus might be necessary. When an animal feeds or dirnks it does not always indulge exclusively in eating or drinking behavior (McFarland, 1978). Eating or drinking is often interspersed with activities such as grooming, listening to disturbances from the outside (like slamming of doors and distracting behaviors of other animals, and the presences of experimenters). The possibility of error in measurement must be considered, especially when more than one experimenter is responsible for data. It is also suggested that, within the context of an experiment such as the one detailed in this paper, an alley be used rather than a T-maze so as to eliminate the possibility of the animal's making a wrong turn at the arms of the T. The T-maze also leaves open the possibility that not all the animals learned that there was food in the black arm. If a T-maze is used and the animals go into the white arm of the extension they should be kept there for a period of five minutes before being returned to their home cages. This would eliminate the possibility that being returned to the home cages is seen as a reward for entering the white arm.

The caloric content of the different foods used should be equalized and the total caloric intake of the animals over a period of time should be measured. With normal satiated animals this was not a concern but could be incorporated in future experiments.

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