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Behavioral Analysis of Marijuana Effects on Food Intake in Humans

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FOLTIN, R. W., J. V. BRADY AND M. W. FISCHMAN. *Behavioral analysis of marijuana effects on food intake in humans*. PHARMACOL BIOCHEM BEHAV **25**(3) 577–582, 1986.—Nine male research volunteers, in three groups of three subjects each, resided in a residential laboratory for up to 25 days. All contact with the experimenter was through a networked computer system and subjects' behaviors including food intake were continuously recorded. Subjects brought their own activities such as model-making, and these in combination with those provided by the laboratory resulted in rich behavior repertoires. During the first part of the day, subjects remained in their private rooms doing planned work activities, and during the remainder of the day, they were allowed to socialize. Cigarettes containing active marijuana (1.84% THC) or placebo were smoked prior to the private work period and during the social access period. A single active marijuana cigarette prior to the private work period had no effect on food intake. The administration of two or three active marijuana cigarettes during the social access period increased average daily caloric intake. The increased intake was due to an augmentation of calories consumed as between-meal snack items rather than an increase in meal size per se.

Marijuana THC Cannabis Food intake Eating Humans

THERE are numerous anecdotal accounts of marijuana induced increases in appetite and food intake in humans [2, 10, 11, 16, 17]. Laboratory studies involving single dose marijuana administration confirm increased eating (or appetite) following oral administration [12] and smoked marijuana administration [1]. Administration of oral marijuana to inpatient clinical populations has been reported to increase appetite [15] and food intake [9]. In addition, two studies have investigated the effects of repeated marijuana cigarette smoking in experienced users residing continuously on a research ward. The first of these studies [18] reported weight gain during a 39 day period of drug administration, and the second study [6] reported weight gain and increased total daily caloric intake during a 21 day period of marijuana administration.

The above studies have demonstrated that either single or repeated doses of marijuana produce increases in food intake and weight gain. The behavioral mechanism(s) responsible for the increased intake have not yet been elucidated. Whether the greater daily caloric intake is attributable to an increase in the size, number, or character of eating episodes (or some combination of these) remains to be determined. Anecdotal accounts suggest that marijuana specifically increases the desire for sweets [2, 11, 17].

In the present study, subjects resided, continuously, in groups of three in a residential laboratory for periods up to 25 days under conditions which involved close monitoring of all food intake. In addition, the effects of smoked active marijuana and placebo cigarettes on total daily caloric intake from meals and between meal snacks was measured.

METHOD

Subjects

Nine healthy adult male research volunteers ranging in age from 22 to 38 participated. All were unrestrained eaters (Stunkard Restraint Scale) and had verifiable histories of marijuana use ranging from two to three cigarettes per week to 15 to 20 cigarettes per week. Subjects received complete medical and psychiatric examinations and signed consent forms detailing all aspects of the research including the fact that their food intake would be measured. Body weight was measured once immediately before and once immediately after each experiment for all subjects. Each volunteer received between $400 and $600 for participating in the study.

Laboratory

Experiments were conducted in a residential laboratory designed for continuous observation of human behavior over extended periods of time. The facility consists of five rooms connected by a common corridor. Three identical private rooms are similar to small efficiency apartments with kitchen, bathroom, desks and sleeping areas. The common social area has a recreation room, an exercise room and a bathroom. The recreation room contains kitchen facilities, lounge furniture, a variety of games, puzzles and a videogame system, while the exercise room contains an array of exercise equipment and laundry facilities. Two-way cabinets in each room of the laboratory allow the transfer of items between subjects and experimenters without physical contact.

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A detailed description of the laboratory has been published elsewhere [4].

An extensive video and audio monitoring system was interfaced with an adjacent control room. Subjects were continuously observed except in private dressing areas and toilet facilities. A computerized observation program [3] provided for continuous recording of each subject's behavior in categorical form. Communication between subjects and experimenter was kept to a minimum, and was accomplished using a networked computer system with CRT and keyboard terminals in each room of the laboratory interconnected with the CRT and keyboard terminal in the main control room. This networked communication system allowed for continuous on-line interaction between subjects and experimenters. Access to television, radio, mail or newspapers was not permitted during the course of the experiments.

Standard Day

The day consisted of three sections: a private work period, a performance task, and a period of social access. Subjects were awakened at 09:00, ate breakfast, and had a work period from approximately 10:00 to 14:30. During this period, subjects were required to engage in one of four structured tasks provided by the experimenter. They were allowed to eat during this period, but had to do so while concurrently performing a work task. A 30 min lunch break from work was required, and could be initiated by each subject at any time during the work period. A one-hour performance assessment was then completed and was followed by the social access period which lasted from approximately 16:00 to 24:00. During the social access period each subject was permitted to remain in his own private room engaging in private recreational activities (e.g., reading, etc.) or in the social area engaging in social activities (e.g., games, etc.). Subjects were not allowed in each other's room and all social activities were available only in the social area during the period of social access.

Food Monitoring

Food availability was carefully controlled. At 09:00, the first of two boxes of food was placed in the food drawer of each of the three private rooms. This contained approximately 3220–3380 kcal and included snack items as well as items appropriate for breakfast (see Table 1 for a complete list of food items). Each snack item portion size was designed to contain a roughly equivalent energy content. The items in the morning food package were continuously available until the midafternoon performance task. Prior to the social access period, the morning package was reclaimed and a new box of food was placed in each subject's food drawer. This new package was identical to the morning package with the absence of breakfast items. A minimum of two of each of the snack items was in every package and subjects were free to request additional items at any time. The variety of cookies, fruit, and cereal was changed daily. Wrappers for each food were color coded by subject to facilitate data collection. In addition, subjects had free access to instant coffee, tea and water at all times. Consumption of items was closely monitored. Subjects were told that their food intake was continuously monitored by independent observers and were instructed to inform the monitors via the computerized communication system whenever they ate or drank something, specifying substance and portion (with the exception of tap water). Empirical measures obtained previously in this laboratory indicate that these procedures have no effect on total daily intake. Trash was removed and measured twice daily to validate the accuracy of the verbal reports and observer records of food intake, and to control for the possibility of food hoarding.

Subjects were required to initiate a 30 min lunch period anytime during the private work period. Subjects selected one lunch item from a list (see Table 1) of nine freeze-dried meals (Oregon Freeze Dry Food, Albany, OR) to which they added a measured amount of boiling water. All of the snack

TABLE 1
FOOD ITEMS

Breakfast:	Hot cereal (100–170*) & cold cereal (70–110)
	Fresh fruit (70–110)
	Juice (90–110)
	Any snack item
Snack Items:	Sprite (120)
	Cola (120)
	Milk (150)
	Salad and dressing (60)
	Roll and margarine (140)
	Cheese and crackers (190)
	Nut Mix (160)
	Fruit (70–110)
	Plain, Peanut M&Ms (110,120)
	Milky Way (100)
	3-Musketeers (80)
	Fritos (120)
	Doritos (80)
	Potato chips (75)
	Cookies (120–180)
Lunch Items:	Freeze-dried food—any of 9 varieties (340–560)
	Chicken Stew
	Chili Mac
	Beef Almondine
	Beef and Rice with Onions
	Granola with Milk and Blueberries
	Noodles and Chicken
	Rice and Chicken
	Spaghetti with Meat Sauce
	Turkey Tetrazzini
Dinner Items:	Prepared frozen foods (680–840)
	Stouffer's Cheese Pizza
	Stouffer's Deluxe Pizza
	Stouffer's Lasagna
	Stouffer's Sausage Pizza
	Swanson's Hungry-Man Turkey
	Swanson's Hungry-Man Salisbury Steak
	Swanson's Hungry-Man Boneless Chicken
	Swanson's Hungry-Man Beef Pot Pie
	Swanson's Hungry-Man Fish N' Chips
	Swanson's Hungry-Man Chopped Beef Steak
	Swanson's Hungry-Man Veal Parmigiana
	Swanson's Hungry-Man Turkey Pot Pie

*Estimated kcal in parentheses.

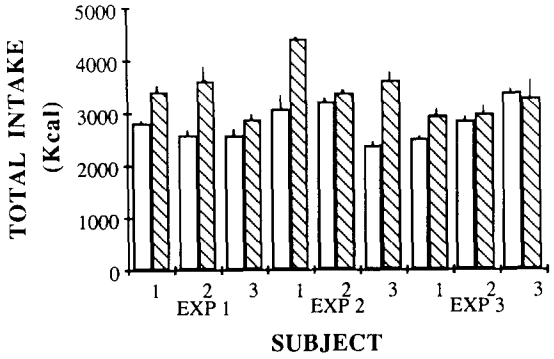

FIG. 1. Mean caloric intake during placebo administration baseline periods (open bars) and active marijuana administration periods (hatched bars) for each individual subject. SEMs are indicated.

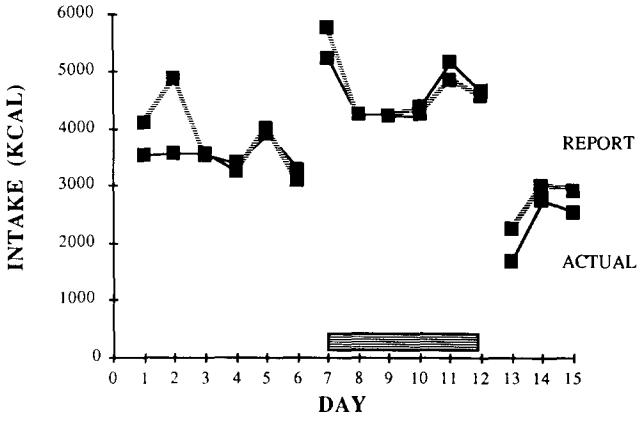

FIG. 2. Total daily caloric intake as a function of day of the experiment for subject 1 in Experiment 2. The dashed lines indicate intake based on verbal reports and the solid lines indicate intake based on inspection of trash and leftovers. Active marijuana was smoked on days 7 through 12 as indicated by the striped bar above the x-axis.

items wree available to be consumed with lunch. Dinner (see Table 1) consisted of a preplanned frozen dinner (Stouffers Foods Corporation, Solon, OH; Campbells Soup Co., Camden, NJ) which could be requested at any time during the social access period prior to 22:30. Multiple dinners could be requested during the social access period. Each subject could consume this meal either alone in his private room or in the recreation area. As with lunch, all of the snack items were available to be consumed with dinner.

An eating occasion (snack or meal) was defined by the reported consumption of any item or series of items. This could be the consumption of a single bag of potato chips or an entire meal with beverage and cookies. A snack was defined by the consumption between meals of any item contained within the box of food. A meal was defined by the consumption of any of the freeze-dried or frozen items that the subjects had to request before eating. A snack with meal was defined by the reported consumption of any snack and meal items at the same time. For example, cookies are a snack item, pizza is a meal item, and when cookies are consumed with a pizza, the combination is a snack with meal. Eating occasions during the private and social periods as well as snack, meal and snack with meal consumption were recorded separately.

Drug Administration

Cigarettes containing 0% (w/w; placebo) or 1.84% (w/w) Δ9-tetrahydrocannabinol, supplied by The National Institute on Drug Abuse, were smoked using a uniform puff procedure cued by stimulus lights located in each room. Onset of the first light signalled that subjects should light the cigarette with minimum inhalation, and then wait for 30 seconds. A series of lights signalled a five second inhalation followed by a 10 second hold, exhalation, and a 45 second rest. This procedure was repeated for three inhalations in Experiment 1 and five inhalations in Experiments 2 and 3. In Experiment 1 (25 days), each subject smoked a placebo or active marijuana cigarette in his individual room at 9:45 and 14:45 and all smoked together in the social area at 19:45. Active marijuana cigarettes were smoked on days 6 through 8 and 18 through 23, while placebo cigarettes were smoked on days 3 through 5 and 9 through 14. In Experiments 2 and 3 (15 days), subjects smoked placebo or active marijuana cigarettes in their individual rooms at 10:00 and 15:25 and together in the social area at 19:25 and 22:00. Active marijuana cigarettes were smoked on days 7 through 12 and placebo cigarettes on days 2 through 6 and 13 through 15.

RESULTS

All subjects adapted readily to the residential facility and total daily food intake stabilized rapidly under baseline conditions. Figure 1 compares the mean number of kcal consumed by each of the nine subjects under placebo baseline and under active marijuana conditions. Subject 2 in Experiment 1 left the study on day 16; his data are included in the analysis up to that point.

The placebo values shown in Fig. 1 (open bars) were based upon the mean daily caloric intake for a minimum of 3 days immediately preceeding each period of active marijuana. Average total daily intake values under placebo conditions ranged between 2400 and 3400 kcal across subjects. The marijuana values shown in Fig. 1 (hatched bars) were based upon the daily mean caloric intake for all active drug days. Average total daily intake values under active marijuana ranged between 2900 and 4400 kcal across subjects. The mean number of kcal consumed daily under marijuana conditions was consistently greater than the mean number of kcal consumed daily under placebo conditions for eight of the nine subjects participating in the study. This statistically significant difference (paired t-test including all nine subjects, $t(8)=3.31$, $p<0.05$) confirms the effect of marijuana in producing an overall increase in food consumption.

Figure 2 presents data from a single subject (S1, Experiment 2) to illustrate the pattern of intake *across days*, which was generally representative of the marijuana-induced food consumption increase over a typical experimental course. Figure 2 also shows the good correspondence between the subject's verbal report of eating and the food trash analysis of actual intake. The correlation between these two measures across all subjects, $r=.875$, $t(7)=4.78$, was highly significant ($p<0.01$).

Figure 3 presents data from another subject (S3, Experi-

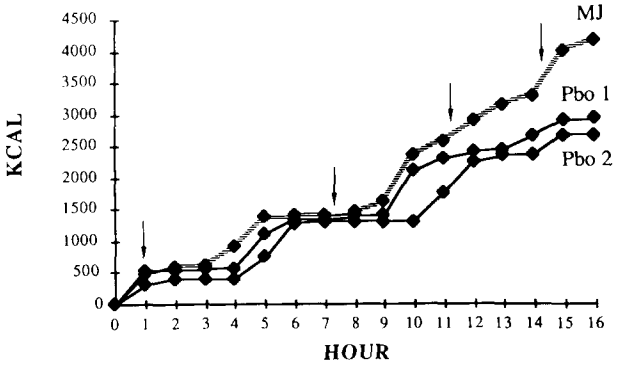

FIG. 3. Mean cumulative daily caloric intake for subject 3 in Experiment 2 during the first period (days 2–6) of placebo administration (Pbo 1), the period (days 7–12) of active marijuana administration (MJ) and the second period (days 13–15) of placebo administration (Pbo 2). Arrows indicate smoking occasions.

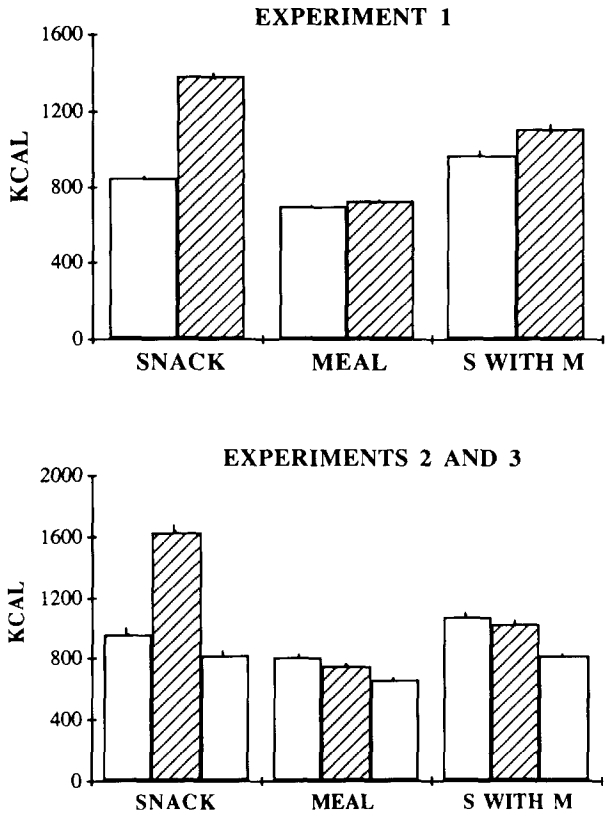

FIG. 4. Mean caloric intake during social access periods from snacks, meals and snacks with meals (S with M). Open bars indicate placebo administration and hatched bars indicate active marijuana administration. Top panel: Experiment 1, n=3. Bottom panel: Experiments 2 and 3, n=6. SEMs are indicated.

ment 2) to illustrate the pattern of intake *within days*, which was generally representative of the marijuana-induced food consumption increase over a typical experimental course. There was little or no difference in food intake between active marijuana and placebo conditions during the private period (hours 0–7). During the social access period however (hours 8–16), markedly greater increases in food intake occurred under active marijuana conditions as compared to placebo. The consistency of these findings across all subjects was confirmed statistically. Mean caloric daily intake for all subjects during private work periods under active marijuana conditions was not significantly different from mean caloric daily intake for all subjects during private work periods under placebo conditions, $t(8)=2.25$, $p<0.10$. During social access periods, in contrast, the average mean caloric daily intake increase of 757.8 kcal across all subjects under active marijuana as compared to placebo conditions was highly significant, $t(8)=5.66$, $p<0.001$).

The food intake data during social access periods (where significant consumption increases occurred) were analyzed in three categories: (1) snacks, (2) meals, and (3) snacks with meals. The "snack" category included items eaten from the standard food box at any time other than with a meal. The "meals" category included only the frozen or freeze-dried entrees requested by the subjects at meal times and consumed alone without snacks. The "snack with meals" category included the total caloric intake on occasions when meal items and snacks were consumed at the same time.

The results of this analysis are presented in Fig. 4 which summarizes the findings for all three experiments. The top panel compares the mean caloric daily intake under placebo (open bars) and active marijuana (hatched bars) in each of the indicated categories averaged across all three subjects during the social access periods of Experiment 1. This experiment involved two separate active marijuana periods (3 and 6 days, respectively) interspersed between placebo periods (3 and 6 days, respectively) with three cigarettes per day and three inhalations per cigarette. The bottom panel compares the mean caloric daily intake under placebo (open bars) and active marijuana (hatched bars) in each of the indicated categories averaged across all six subjects during the social access periods of Experiments 2 and 3. These latter two experiments involved a single active marijuana period (6 days) bracketed by two placebo periods (5 days "pre" and 3 days "post") with five cigarettes per day and five inhalations per cigarette. Both panels of Fig. 4 show that only the consumption of snack items was consistently increased under active marijuana conditions. In Experiment 1 (top panel), intake in the snack category increased 63% under active marijuana conditions as compared to placebo with little or no difference between the conditions in the other two categories. Similarly, in Experiments 2 and 3 (bottom panel), the snack category was the only one in which consumption was significantly increased under active marijuana conditions as compared to placebo (Friedman's sample, $r^2(2)=7.0$, $p<0.05$).

Figure 5 presents the results of an analysis of the number of *eating occasions* during the social access periods and summarizes the findings for all three experiments. The top panel compares the mean number of eating occasions under placebo (open bars) and active marijuana (hatched bars) for each of the three subjects during the social access periods of Experiment 1. The bottom panel compares the mean number of eating occasions under placebo (open bars) and active marijuana (hatched bars) averaged across all six subjects during the social access periods of Experiments 2 and 3. Both panels of Fig. 5 show that the number of eating occasions was consistently increased under active marijuana conditions. In Experiment 1 (top panel), all three subjects increased the number of eating occasions under active marijuana conditions compared to placebo. Similarly, the

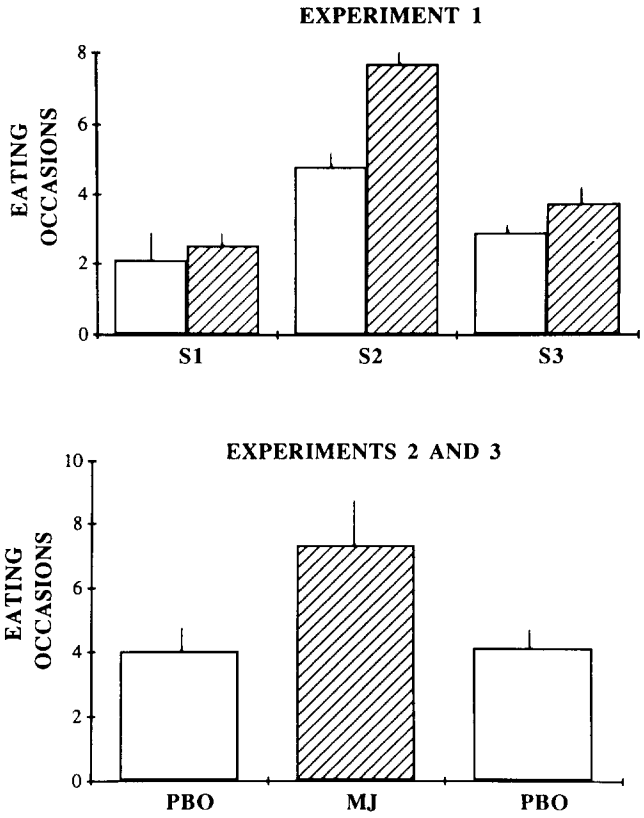

FIG. 5. Mean number of eating occasions during social access periods. Open bars indicate placebo administration and hatched bars indicate active marijuana administration. Top panel: Each subject in Experiment 1. Bottom Panel: Experiments 2 and 3, n=6. SEMs are indicated.

data from Experiments 2 and 3 (bottom panel) show that the number of eating occasions increased 70% under active marijuana conditions as compared to placebo. This statistically significant difference (Friedman's k-sample, $r^2(2)=9.33$, $p<0.01$) provides evidence that changes in frequency of eating occasions played an important role in mediating the effect of marijuana on food intake.

Total daily caloric intake for all subjects was analyzed for the three macronutrients using Atwater factors [14]: 10% protein, 35% fat, and 55% carbohydrate throughout the study. No differences between placebo and active marijuana conditions were revealed by this analysis. In addition, there were no differences in the body weight measures taken before and after each experiment which could be related to the marijuana-induced changes in food intake.

DISCUSSION

The results of these experiments show clearly that smoked marijuana can produce significant increases in food intake with small groups of subjects in a residential laboratory setting under conditions of continuous confinement for periods of several weeks. These findings are in accord with the several anecdotal reports of marijuana-induced increases in food intake [2, 10, 11, 16, 17] as well as with studies describing selective increases in the consumption of food substances following acute administration of marijuana in laboratory settings [1, 12, 13].

Accurate measures of daily caloric intake and changes in weight during an 11 day period when subjects could self-administer marijuana cigarettes have been reported previously [6]. In that study, casual users (2–3 times a week) smoked approximately two cigarettes per day and food intake increased by 15% for the entire period, while heavy users (7–10 times a week) smoked about five cigarettes per day and showed an increase in food intake only on the first day of drug availability. Both groups of users gained weight, and there was a sharp decline in food intake following cessation of drug availability. A similar trend toward declining food consumption during post marijuana periods was observed in the present study. This decline in food intake occurred in only a few of the subjects and is reflected in a comparison of the pre- and post-drug caloric values shown in Figs. 3 and 4 (Experiments 2 and 3).

Smoking a single active marijuana cigarette prior to the private work period had no effect on food intake in the present study. Snack food consumption was significantly increased however, when one or two active marijuana cigarettes were smoked in a group in the social area. Marijuana, perhaps more than any other illicit drug, is used predominantly in a social context [5]. Under such circumstances, it seems likely that interactive social effects may have played a part in the food consumption increases described in this report. That such social setting factors are not the sole determinant of the present findings however is indicated by the probable elevated THC blood levels following multiple marijuana cigarette administration during the social period which could account, at least in part, for the observed increases in food intake. Additionally, interactions between drug effects and established time-of-day eating patterns must be taken into account, as well as differences in the kind of foods available for consumption (e.g., freeze-dried lunch items, frozen dinners, etc.). While data from the present experiment do not permit a partitioning of these multiple potential determinants, the research design does approximate conditions in the natural environment, and the results seem most parsimoniously interpreted in terms of the interacting effects of drug dose and social influence upon food intake.

The results of the present study also provide strong indications of the behavioral mechanisms involved in the marijuana-induced food consumption increases. The data summarized in Figs. 4 and 5 show clearly that an increase in the calories consumed as between meal snacks and in the frequency of eating occasions were the dominant factors in accounting for the food intake augmentation. While these findings are generally consistent with previously reported marijuana effects on sweets and snack food intake [2, 11, 17], the present data did not permit an analysis on the basis of taste class alone. Such an analysis of taste class has proven useful in understanding the effects of nicotine on food intake and body weight where it is evident that nicotine specifically decreases consumption of sweet-snack food items [7,8]. It is of obvious theoretical and practical importance to determine whether the increase in snack food intake is a function of taste factors or whether such consumption increases are attributable primarily to accessibility factors. Clearly, further research on the role of social factors, food type, and food accessibility in determining the effects of smoked marijuana on food intake will be required.

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