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Behavioral Economic Analysis of Smoking: Money and Food as Alternatives[1]

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EPSTEIN, L. H., C. M. BULIK, K. A. PERKINS, A. R. CAGGIULA AND J. RODEFER. *Behavioral economic analysis of smoking: Money and food as alternatives.* PHARMACOL BIOCHEM BEHAV **38**(4) 715–721, 1991.—The relative reinforcing value of smoking versus two nonpharmacological reinforcers, money and food, was evaluated in young female smokers in two experiments. In Experiment 1 eight smokers worked for access to smoking or money on concurrent progressive variable ratio schedules of reinforcement (VR4 to VR50) across two days of Smoking Deprivation or No Deprivation. During No Deprivation money was reliably chosen over smoking. During Deprivation subjects initially (VR4) chose smoking over money, but at subsequent comparisons allocated equal time to work for smoking or money. In Experiment 2 eight smokers were provided access to smoking or food across four conditions: No Deprivation, Smoking Deprivation, Food Deprivation and Smoking + Food Deprivation, using the same progressive variable ratio schedules as in Experiment 1. Results showed an increase in the reinforcing value of food after Food Deprivation and smoking after Smoking Deprivation. On the dual deprivation day, subjects initially (VR4) chose to work for food, showed equal preferences over the next three schedule comparisons (VR8–VR20), and from VR25–VR50 shifted their choice to smoking. An increase in percent of calories as fat was observed during all deprivation conditions. The results demonstrate the use of the concurrent schedule paradigm for assessing choice among pharmacological and nonpharmacological reinforcers, and shows the relative reinforcing value of smoking depends on recent deprivation, response demands to obtain the reinforcer and availability of alternative reinforcers.

Smoking Behavioral economics Substitutability Reinforcement

THE reinforcing efficacy of a drug is basic to drug dependence. There is an extensive literature using self-administration paradigms to study the reinforcing efficacy of nicotine in animals. Much less is known about self-administration of nicotine in humans (10). Henningfield and colleagues (10–13) have demonstrated that IV nicotine can serve as a reinforcer by comparing response rates for nicotine or saline when they are available on separate days or in a concurrent choice paradigm. In addition, Rose and colleagues (24) showed a preference for increased nicotine concentration in smoke as a function of recent smoking deprivation, consistent with the idea that nicotine serves as a reinforcer for smokers.

The relative reinforcing effects of a drug are influenced by constraints upon access to the drug as well as by drug effects. For example, amount of nicotine intake (10) as well as intake of other drugs (28) decreases as the response requirements to obtain the drug increase. Likewise, the reinforcing effects of a drug are influenced by alternative reinforcers. Carroll, Lac and Nygaard (3) showed that access to sweetened water could reduce the relative reinforcing value of cocaine, and removal of sweetened water could produce an increase in the reinforcing value of cocaine. No research in humans has yet studied concurrent access to smoking versus nonpharmacological reinforcers.

Behavioral economic theory provides a framework for analyzing factors that influence choice (1,22). Behavioral economic paradigms provide subjects access to alternative activities or reinforcers that vary in their accessibility. By comparing the response patterns to obtain the alternatives, the relative reinforcing value of pharmacological and nonpharmacological reinforcers can be compared, and the influence of nonpharmacological substitutes assessed (28). One implication of behavioral economic theory is that the reinforcing value of smoking, or any commodity, is a function of the constraints on smoking (cost, availability, response demands) and the alternative reinforcers available. While this contextual specificity of the reinforcing effects of smoking limits generalization to the conditions studied, it is hoped that with carefully designed experiments general principles relevant for understanding the relative reinforcing effects of various pharmacological and nonpharmacological reinforcers will emerge, along with clues to more successful drug treatment. For example, behavioral economics suggests treatments for drug abuse may be more successful if adequate behavioral substitutes for drugs are found (28).

In this paper we present two experiments designed to develop and test a self-administration choice model for studying smoking in young female smokers. Experiment 1 compares the reinforcing

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value of smoking with money, a powerful instrumental reinforcer. In previous research we showed that constraints on access to food or money influenced choice, such that monetary reinforcers were chosen over food, even after food deprivation (16). Monetary incentives are often used to reinforce abstinence or decreases in smoking behavior (2,27), suggesting that under some conditions this generalized reinforcer can substitute for smoking.

Experiment 2 is designed to assess the relative reinforcing value of smoking versus food. The reinforcing value of food versus pharmacological reinforcers has been studied in several ways. In paradigms in which drugs and food are available under concurrent progressive schedules of reinforcement, choice varies as a function of the schedules of reinforcement (14). For example, Elsmore, Fletcher, Conrad and Sodetz (7) showed monkeys' choice of heroin was directly related to response demands, described by an elastic demand curve. On the other hand, the amount of food obtained remained constant over a wide range of response demands, a characteristic of inelastic demand curves. These data suggest that if access to drugs and food are under equivalent constraints, food may be differentially chosen or preferred to drugs as response demands increase (14). In paradigms in which animals become dependent upon drugs with ad lib access to food, food deprivation leads to an increase in drug intake (4). Thus, when access to food is limited, the reinforcing efficacy of a drug may increase. Likewise, if subjects were attempting to lose weight and thus food deprived, but no constraints were placed on smoking, then smoking may increase and serve as a substitute commodity for food. By differentially depriving subjects of both commodities and placing them under progressive constraints Experiment 2 tests the substitutability of food and smoking.

EXPERIMENT 1

Subjects

Eight female smokers (ages 18–19) were recruited from the community for participation in the study. Subjects smoked a minimum of 15 cigarettes per day (20.0 ± 4.6; mean $\pm$ S.D.), with an average nicotine yield of 0.93 ± 0.18 mg, and had been smoking for an average of 2.7 ± 1.3 years. No subjects had attempted to quit smoking or changed the average number of cigarettes they were smoking within the previous six months. Subjects were paid $40.00 for their participation in the study.

Procedure

The experiment was run during four consecutive afternoons. Each subject participated in two consecutive days in the Deprivation and No Deprivation conditions, with order counterbalanced across subjects. During Deprivation, subjects were asked not to smoke from midnight the night before. Compliance with Deprivation instructions was assessed using a Vitalograph EC-50 COa monitor (Lenexa, KS), with COa equal to or greater than 9 ppm used as the Deprivation cutoff. There were no restrictions on smoking during No Deprivation. Subjects in this condition smoked one cigarette after baseline COa which was five minutes before the experiment began to equate time since last cigarette.

Subjects had the opportunity to obtain money or puffs on a cigarette of their usual brand by earning points on Apple Picker, a concurrent schedule task programmed on an Apple IIe microcomputer (19). Apple Picker provides subjects the opportunity to work in either of two fields (X and O), each of which was associated with its own reinforcement schedule. Each field ("orchard") was composed of a grid of symbols ("trees"). Subjects used a joystick to move the screen cursor from tree to tree, to switch fields and to pick apples. Reinforcement schedules were implemented by varying the probability of obtaining points ("apples") in each field which were exchanged for the reinforcers on the basis of item price.

Point totals were displayed to each subject in each schedule. Five points earned subjects either $0.10 or one puff on their cigarette. The schedules for obtaining each point increased progressively from VR4, VR8, VR12, VR16, VR20, VR25, VR33, through VR50, with the schedule increasing after each subject earned two reinforcers. No verbal instructions of schedule changes were provided, and subjects practiced on each schedule for one minute prior to each schedule comparison, or trial. If a subject earned both food and money during a trial, then she was asked which she wanted first. Reinforcers were delivered at the end of each trial.

Previous research with animals and humans (10) has shown that access to nicotine must be limited to maintain nicotine as a reinforcer within a session. We attempted to prevent satiation and maintain reinforcer effectiveness by limiting access to a maximum of two puffs per schedule (a maximum of 16 total puffs). Based on the time to complete schedules and obtain reinforcers, it took the average subject approximately 26 minutes to obtain the first 8 puffs on her cigarette if she worked only for smoking. As schedule requirements increased, time to obtain reinforcers increased, and it took approximately 47 additional minutes to obtain her next 8 puffs. COa was measured after each of the eight smoking trials to assess smoking exposure.

Measurements and Analysis of Data

The primary dependent measure was the number of points (instrumental reinforcers) obtained working for smoking or money. Subjects worked in each schedule comparison until enough points were accumulated to obtain a total of two smoking or monetary reinforcers. Points directly reflected response allocation, and provided a more detailed analysis of responding than the number of reinforcers. Presentation of reinforcers would limit analyses to two reinforcers per schedule. Points allocated for each reinforcer were also preferred to number of responses, since total points were held constant across schedule comparisons, while response rate increased as a direct function of progressive schedule requirements. Thus changes in response rate over trials would be a function of schedule requirements, and not necessarily directly reflecting response allocation.

Separate within-subject analyses of variance were performed for Deprivation and No Deprivation conditions with Type of Reinforcer (Smoking/Money) as one factor and Schedule (VR4–VR50) as the second factor. To ensure there was stability across days, the first analyses were repeated measures analyses of variance for each dependent variable across Days within Conditions for the 8 Schedule comparisons. Since no effects of days were shown the final analysis combined results across days. Planned a priori comparisons were completed for the number of smoking or money points obtained during Deprivation or No Deprivation conditions using Dunn's multiple comparison, which adjusts for the number of comparisons made. The planned comparisons were built into the experimental design and were not dependent upon significant main or interactive effects. However, for completeness of presentation main or interactive effects are presented.

COa results were first analyzed to ensure stability across days, and then a two-factor repeated measures analysis of variance was used to assess the effects of Condition and Schedule.

RESULTS

Comparison of points earned during Deprivation (Fig. 1, left graph) showed no significant effects of type of reinforcer, $F(1,7) =$

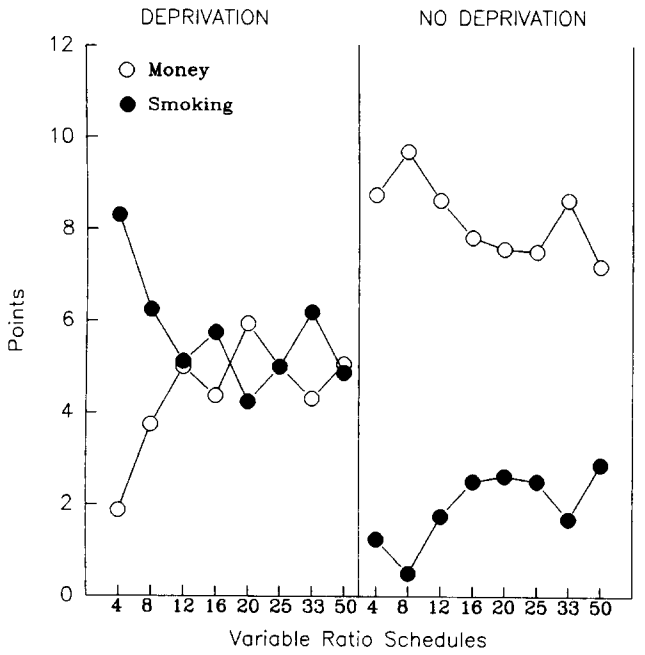

FIG. 1. Number of reinforcers earned for smoking or money during Deprivation or No Deprivation conditions in Experiment 1. Data represent the means of two sessions in each condition.

TABLE 1

CHARACTERISTICS OF FOOD REINFORCERS

Food	Amount	Pts	Cal	Prot	Grams Fat	Carbo
American Cheese	1 slice	7	92	5.6	6.8	2.0
Apple	1 medium	4	80	0.3	0.8	20.0
Bagel	1	10	163	6.0	1.4	30.9
Bread	1 slice	5	61	2.6	0.8	11.9
Butter	1 pat	2	36	0.0	4.1	0.0
Choc Chip Cookies	2	5	50	0.6	2.2	7.4
Crackers	2	2	34.8	0.5	1.4	5.1
Cream Cheese	1 Tbsp	4	52	1.1	5.3	0.3
Ham	2 slices	7	98	8.0	7.2	0.0
Ice Cream	1 cup	6	257	6.0	14.1	27.7
Jam	1 Tbsp	4	54	0.1	0.0	14.0
Milk 2%	8 oz.	5	145	10.3	4.9	14.8
Miracle Whip	1 Tbsp	2	101	0.2	11.2	0.3
Mustard	1 Tbsp	2	4	0.2	0.2	0.3
Orange Juice	8 oz.	5	112	1.7	0.5	25.8
Peanut Butter	1 Tbsp	5	94	4.0	8.1	3.0
Turkey	2 slices	7	84	10.3	4.0	1.2
Water	8 oz.	1	0.0	0.0	0.0	0.0

0.87, $p=0.38$, schedule, $F(7,49)=1.28$, $p=0.28$, or an interaction between cigarettes and money, $F(7,49)=1.78$, $p=0.11$. While these results show that in general no significant preference for smoking or money was shown during Deprivation, planned comparisons did show significant differences ($p<0.05$) for response allocation for the VR4 schedule comparison. During VR4 deprived subjects allocated more points for smoking than money, but no differences between choice of smoking or money were obtained on any subsequent schedules. On the other hand, analysis of the No Deprivation data showed a significant main effect of reinforcer, $F(1,7)=32.95$, $p=0.001$. Planned comparisons showed significant differences ($p<0.05$) for response allocation between smoking and money with nondeprived subjects allocating more points for money than smoking at each opportunity.

COa showed an interaction of Conditions × Schedules, $F(8,48)=29.32$, $p<0.001$. During Deprivation, COa values increased significantly ($p<0.05$) from pre (6.4 ± 3.1) to the first smoking opportunity at VR4 (11.6 ± 4.9), with further increases in COa up to VR16 (14.9 ± 6.2). After VR16 COa remained stable. All COa values collected during Deprivation were significantly below those during No Deprivation. During No Deprivation COa values remained relatively stable, though a decrease from baseline to the end of the session (27.6 ± 12.0 to 22.9 ± 9.9) was observed ($p<0.05$).

EXPERIMENT 2

Subjects

Eight female smokers (21.6 ± 2.3 years of age; mean ± S.D.) recruited from the community served as subjects. They smoked a minimum of 15 cigarettes per day (20.0 ± 2.7;), with an average nicotine yield of 0.80 ± 0.21 mg, and had been smoking for an average of 5.1 ± 3.7 years. No subject had attempted to quit smoking or changed the average number of cigarettes she was smoking within the previous six months. Sections of the Structured Clinical Interview for DSMIII-R (26) were administered to screen for presence of anorexia or bulimia nervosa. One potential subject was excluded due to a current diagnosis of bulimia nervosa. Subjects were paid $40.00 for their participation in the experiment.

Procedure

The experiment was run on four consecutive days during hours when the subjects ate dinner (1600–1930 hours), a slightly longer smoking deprivation interval than in Experiment 1 when subjects were deprived from midnight to the next afternoon. Subjects participated in four conditions in a randomized order: No deprivation, Smoking Deprivation, Food Deprivation and both Smoking + Food Deprivation. On Smoking Deprivation days subjects were asked to refrain from smoking from midnight the evening before the experiment. On Food Deprivation days subjects were instructed to have a light breakfast (e.g., toast and coffee) with no caloric and/or caffeinated beverages/food for 7 hours preceding the experiment. Compliance with food deprivation instructions was assessed using daily food diaries reviewed by the experimenter. Smoking restriction was assessed using a Vitalograph EC-50 COa monitor. COa equal to or greater than 9 ppm was used as criterion for smoking.

At the beginning of each session subjects completed a 10-point Likert scale assessing their hunger and craving for a cigarette. They then had access to the same schedules as in Experiment 1. However, there were several differences in methods in Experiment 2. In Experiment 1 each schedule was in effect until two reinforcers were earned, which meant that as schedule requirements increased intersmoking intervals also increased and increased deprivation may have occurred. In the present experiment each schedule was compared over 3-minute periods, similar to previous experiments from this laboratory (8,16). In this paradigm more points could be obtained during schedules that re-

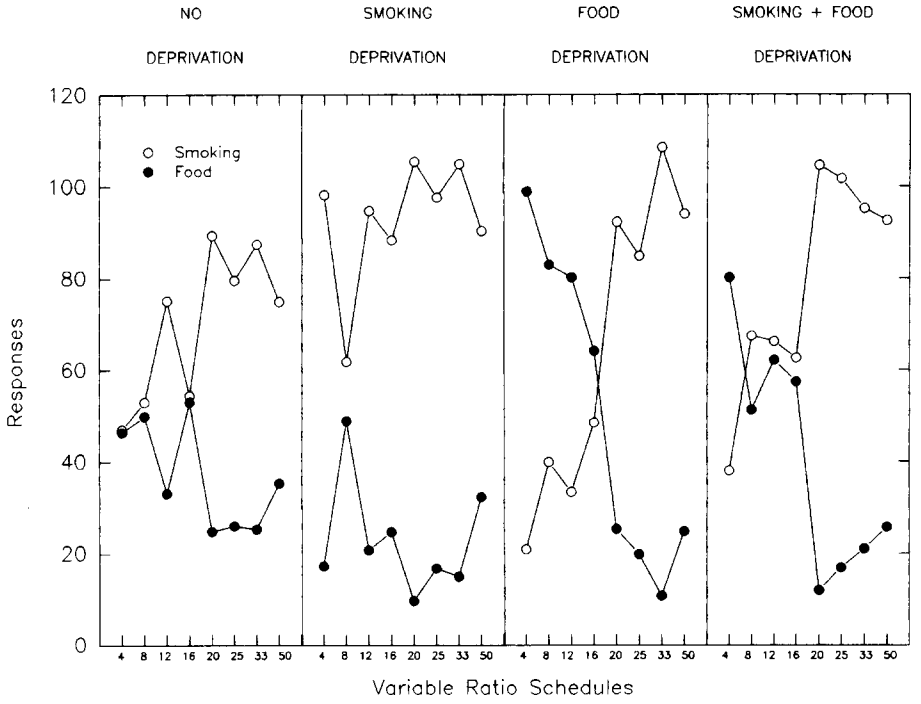

FIG. 2. Responses for smoking or food during No Deprivation, Smoking Deprivation, Food Deprivation or the combination of Smoking + Food Deprivation in Experiment 2.

quired fewer responses, but intervals between smoking opportunities are held constant.

In this experiment two points could be exchanged for one puff of smoking. Points for food were arranged so that subjects could obtain a typical lunch, including a sandwich, drink and dessert by the third of the four occasions for reinforcement delivery. As a check on the relationship between point assignment and food value, research staff were asked to rate the relative worth of the foods used on a 1 to 10 point scale, and the correlation between staff ratings and points was r = .76. Characteristics of the food reinforcers and their point values are presented in Table 1. Each of the eight schedules was preceded by two minutes of practice to give subjects the opportunity to discover the availability of apples on each of the two fields.

Finally, in Experiment 1, the points were totalled and reinforcers available after each trial, but in Experiment 2 points earned for both cigarettes and food were totalled and reinforcers provided after every other trial. This change was designed to maintain deprivation by having approximately 25 minutes elapse between reinforcer delivery. Subjects had to complete each puff earned and/or eat all the food provided. COa was assessed prior to reinforcer delivery. If both reinforcers were earned, subjects were asked which one they wanted first.

Measurements and Analysis of Data

The primary measure of choice was number of responses allocated for smoking or food. In this paradigm in which time was held constant across schedule comparisons, number of responses reflects choice better than points or reinforcers earned. While total response rate stayed relatively constant across schedules, with the allocation of responses varying as a function of choice, points and reinforcers earned decreased as a function of schedule requirements. This limits information about choice based on these measures as fewer reinforcers were available in the time period. Additional dependent measures included COa, food intake (total calories, percent of calories as fat, carbohydrates, and protein), and subjective ratings when the session began.

Allocation of responses for the alternatives were analyzed across sessions using within subject analyses of variance, with Reinforcer and Schedule as the within factors. Planned comparisons were completed for the number of smoking or money reinforcers obtained for each condition using Dunn's multiple comparison procedure.

Within subjects ANOVA was used to analyze COa, with Conditions and Schedules as the within factors. Characteristics of food intake and baseline differences across sessions were analyzed using one-way repeated measures ANOVA's, with Conditions as the within factor.

RESULTS

Baseline Cigarette Craving and Hunger Results

Cigarette cravings were significantly different across sessions, $F(3,21) = 25.63$, $p < 0.001$. Ratings were higher for sessions involving smoking deprivation (Smoking Deprivation = 8.1 ± 0.8; Smoking + Food Deprivation = 8.3 ± 0.5 versus No Deprivation = 4.4 ± 1.8; Food Deprivation = 3.9 ± 2.1). Hunger ratings were also differentially influenced by deprivation, $F(3,21) = 54.21$, $p < 0.001$, with the ratings higher for the two sessions involving food deprivation (Food Deprivation = 8.3 ± 0.5; Smoking and Food Deprivation = 8.3 ± 0.5 than No Deprivation = 3.1 ± 1.4; Smoking Deprivation = 3.6 ± 1.5). These results support the efficacy of the manipulations.

Behavioral Choice Results

The number of responses for the two choices are presented in Fig. 2. In No Deprivation a significant reinforcer effect was

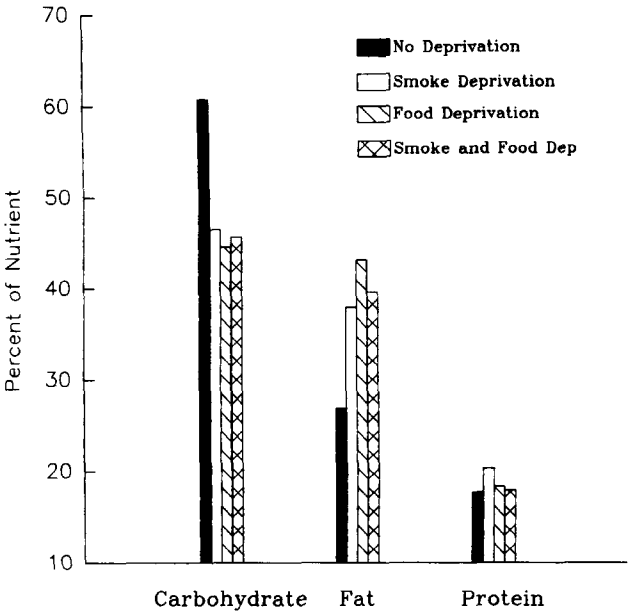

FIG. 3. Percent of fat, carbohydrate and protein for food choices during No Deprivation, Smoking Deprivation, Food Deprivation or the combination of Smoking + Food Deprivation in Experiment 2.

shown, $F(1,7)=7.35$, $p=0.03$. Post hoc analyses showed no consistent differences in response rate for the first three schedule comparisons, but a significant preference for smoking ($p<0.05$) was observed across the last four schedule comparisons (VR20–VR50). During Smoking Deprivation a significant reinforcer effect was again shown, $F(1,7)=37.27$, $p<0.001$, with more responses for smoking ($p<0.05$) for each schedule comparison except for the second schedule (VR8).

Shifts in preference (interaction of Reinforcer × Schedule) from food to smoking were observed for Food Deprivation, $F(7,49)=7.52$, $p<0.001$, and Smoking + Food Deprivation, $F(7,49)=4.69$, $p<0.001$. During Food Deprivation subjects responded more to obtain food for the first three schedules, switched to obtain smoking at VR16, and responded more for smoking from VR20–VR50. During Smoking + Food Deprivation subjects responded more to obtain food at VR4, showed no differences in response patterns from VR8–VR16, and shifted the response patterns towards smoking from VR20–VR50.

Alveolar CO Results

COa data showed a significant interaction of Conditions × Schedules, $F(12,84)=10.54$, $p<0.001$. COa during No deprivation was significantly higher (31.4 ± 15.5 to 36.6 ± 13.4) than during Smoking Deprivation (8.6 ± 3.2 to 28.5 ± 8.5) and Smoking + Food Deprivation (8.1 ± 2.9 to 23.1 ± 6.6) on every trial. COa levels were similar during both Smoking Deprivation and Smoking + Food Deprivation at baseline (8.6 vs. 8.1), but at the VR16 comparison smoke intake was greater for Smoking Deprivation (25.6 ± 9.8) than Smoking + Food Deprivation (18.9 ± 5.4), with significant ($p<0.05$) differences between these two groups from the VR16 through VR50 comparisons.

Caloric Intake and Nutrient Composition

Significant differences in total caloric intake were observed across the four conditions, $F(3,21)=20.75$, $p<0.001$. In comparison with No Deprivation (459.5 ± 226.6), Food Deprivation (722.5 ± 193.2) resulted in significantly ($p<0.05$) increased caloric intake, and Smoking Deprivation (279.6 ± 170.1) resulted in decreased ($p<0.05$) caloric intake. Smoking + Food Deprivation (548.3 ± 97.5) was not different in intake from No Deprivation.

Significant changes were shown in the percent of calories from fats, $F(3,21)=23.47$, $p=0.03$, with significant ($p<0.05$) differences observed between the No Deprivation condition and each of the other conditions (Fig. 3). Any deprivation, whether it was of food or smoking, increased the percentage of food eaten that contained fat. No significant changes in carbohydrate, $F(3,21)=2.32$, $p=0.10$, or protein intake were observed.

DISCUSSION

The results of these two experiments demonstrate behavioral choice methodology can be used to study the relative reinforcing value of smoking versus alternative activities. Experiment 1 showed that when smokers were not deprived of smoking, they chose to work for money, a generalized reinforcer. However, they were able to obtain sufficient amounts of smoke from their limited access to cigarettes to maintain their elevated COa levels. During smoking deprivation subjects initially responded more for smoking than money, and in subsequent trials worked equally hard for smoking and money. Thus deprivation shifted preference towards smoking. However, the fact that smokers did not choose smoking over money after smoking deprivation was surprising, particularly since the experimental methods limited access to no more than two puffs after each schedule was completed, and COa values for deprivation remained significantly below nondeprivation values. It is possible that the limited effects of deprivation on smoking were due in part to the open economy nature of the experiment since session length was short and subjects had access to smoking at the termination of the experimental session. Results may have been different if the experiment was run under a closed economy, in which session length was extended and access to smoking or other reinforcers were limited and under experimental control (14).

Experiment 2 investigated the relationship between smoking and food alternatives. In the reference No Deprivation condition subjects initially responded equally for smoking or food, and then switched to allocate responses to smoking. During Smoking Deprivation subjects allocated the majority of responses for smoking throughout all comparisons. On the other hand, during Food Deprivation, subjects responded more for food initially and this pattern extended over several schedule comparisons, though subjects eventually began to work harder for smoking rather than food. The combination of Smoking + Food Deprivation provided a test of which commodity was immediately more reinforcing, and the initial choice was for food. During the next three comparisons subjects responded equally for smoking or food, and then shifted to respond for smoking.

The results suggest under the conditions of Experiment 2 there was limited substitutability between smoking and food when both alternatives were concurrently available, since after deprivation subjects did not increase their intake of the alternative commodity. Thus the observation that smokers may eat less when smoking (20) does not seem to be based on smokers using smoking as a substitute for food. A different paradigm, in which the reinforcing value of a drug is assessed when food is not available, may have produced different results.

Perhaps the most meaningful comparisons between the com-

modities is when they are both deprived, leading to both hunger and cigarette craving. In the conditions of this experiment food was generally more reinforcing than smoking. One important difference between smoking and food as reinforcers is the typical patterns of consummatory behavior. The main reinforcing component of cigarettes is believed to be nicotine (23). Nicotine acts quickly, with a distribution half-life of only 9 minutes (9). It was possible to keep subjects responding for smoking by manipulating access to number of puffs (Experiment 1) or intersmoking interval (Experiment 2). On the other hand, food is consumed at much less frequent intervals than smokers use cigarettes. Satiation after eating lasts much longer than smoking. Satiety is a direct function of the amount of food consumed, and may last for several hours after eating. The process of digestion is much slower than the drug action of nicotine (5). There may be many limitations to comparing rates of consumption of food and smoking, and future experiments should compare reinforcers that share more similar characteristics. The relationship between smoking and eating is complex, and smokers often smoke when they are not deprived of food. In fact, eating may prime smoking, either as a discriminative stimulus for eating or as a complement to smoking (15).

The differences in consummatory patterns of smoking and food highlight a basic issue in finding alternative reinforcers for smoking cessation. Many substitutes for smoking have been used in treatment programs, such as exercise (25) or relaxation (17). These alternatives have been tried empirically, with no attempt to understand the relative reinforcing value of these alternatives, and whether these alternatives do in fact compete with smoking. Each of these alternative reinforcers, like food, is substantially different from smoking in the duration of reinforcing effects, the number of times the reinforcer can be implemented, and the general availability of the alternative.

In addition to the influence of the schedules for earning points, the specific rates of exchange from points to reinforcers used in Experiments 1 and 2 may have influenced the results. In Experiment 2 nondeprived subjects showed equal preference for smoking or food at the VR4 comparison, suggesting the alternatives were equally reinforcing at the exchange rate used, a constant amount of food versus 0.5 puffs. In Experiment 1 a marked preference for money rather than smoking was observed during no deprivation at the VR4 comparison when the exchange rate was 1 puff versus $0.10 per reinforcer. Additional parametric work is needed to equate the relative reinforcing value of food and money for future studies.

One potential problem with the use of progressive schedules to assess choice for two alternatives is the absence of a control group that has similar exposure to the alternatives, but repeated presentation of the same nonprogressive schedule. For example, it is possible that the shifts in response patterns for smoking and money or smoking and food would have been the same with extended exposure to the reinforcers, even if response characteristics had remained constant. A second problem when using progressive schedules of reinforcement is the correlation of increasing schedule requirements with time. As the session progresses, the subject has the opportunity to accumulate more of the reinforcer, but also the schedule requirements have increased and the reinforcer is harder to get. Since the increased schedules are presented after the subject may have consumed some of the reinforcer, it is possible that the changes in reinforcer effectiveness as assessed by the changes in schedules were due in part to changing patterns of satiation to the reinforcers. This is less of a problem in designs that compare schedules across days, rather than within the same day.

There is another concurrent schedule paradigm we have used in other experiments (8,16). In this paradigm the schedule for one alternative remains constant, and the schedules are varied for the other option. We have used this paradigm when there is a large initial difference in choice between the two alternatives, either due to individual differences (8) or characteristics of the alternatives (16), and the schedule changes are designed to assess the influence of constraints for the more preferred option. For example, when children are given the option of highly preferred sedentary activities versus less preferred vigorous activities, children work for the sedentary activity. However, if response demands are kept constant for the vigorous activity but increase for the sedentary option, then children shift their responses to the vigorous option, with the shifts occurring in direct relation to the extent of their obesity. Other experiments (7) have shown changes in the pattern of response when responding for two alternatives is equated but constraints on the two alternatives change together, providing a model for the current experiment in which initial responding for food and smoking was equated under no deprivation.

The amount of food chosen was directly influenced by deprivation, with subjects in the Smoking Deprived condition choosing the least food and subjects in the Food Deprived condition the most food. It is more interesting that after each of the deprivation conditions, subjects chose foods with higher fat content. The percentage of calories from fat content went from about 30% during no deprivation to 40% when deprived. One interpretation of this effect is based on increased hedonic value of foods high in both fat and sugar relative to sugar alone (6). Thus, in the choice of foods, subjects may have selected ones that would increase their relative hedonic (reinforcing) value, thus competing with the lack of available reinforcers due to deprivation. This mechanism is highly speculative, and demands further research, but might help explain variables that influence food selection and relationships between types of food and alternative reinforcers.

These experiments attempted to compare alternatives for smoking using behavioral choice methods. While these methods are very flexible, the results of each comparison are limited to the particular set of conditions studied, and care must be taken before results of any comparison is generalized to other conditions, such as different exchange ratios, subject individual differences (8), and subject manipulations such as deprivation (16). As methods used in this study are replicated in other laboratories, and other nonpharmacological alternatives are tested, then it is hoped that consistencies across classes of reinforcers, tested under specific conditions, will be demonstrated that will provide the basis for a method for categorizing substitutes for drugs.

Finally, this paper focused only on the reinforcing effects of smoking. Dependence on smoking is only partly due to appetitive motivation (18), and a variety of positively reinforcing effects of smoking have been studied. These include the psychoactive effects of nicotine on affect, as well as the effects of smoking on other behaviors that are reinforced, such as attention span, memory, and vigilance (21). To compete with the reinforcing effects of smoking, substitutes may have to address each of these potenially reinforcing aspects of smoking.

In summary, the results of these experiments suggest that concurrent schedule paradigms can be used to study choice between smoking and alternative reinforcers. Future investigations should attempt to increase experimental control over available reinforcers and compare reinforcers that share the same pattern of consumption as smoking.

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