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# Number of foods available at a meal determines the amount consumed

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ABSTRACT

The number of foods available at a meal has been suggested as a major determinant of the amount consumed. Two studies conducted in humans test this idea by altering the number of foods available at a meal where participants eat the available foods ad libitum. In Study 1, dinner intake of twenty-seven young adults was measured. The amount consumed was measured when subjects were served either: (a) a composite meal (a protein rich food, a carbohydrate rich food, and a vegetable), (b) a low carbohydrate meal (protein rich food and vegetable), or (c) a vegetarian meal (carbohydrate rich food and vegetable). In Study 2, twenty-four subjects were given two different meals presented either as individual foods or as a composite meal (stir-fry or stew). Both studies show that the greater the number of foods offered at a meal, the greater the total intake. Study 2 demonstrated that the effects observed in Study 1 could not be attributed to different nutrient compositions, but was rather due to the presentation of the individual foods because the same foods that were offered as individual foods were combined to make the composite meal. The results demonstrate that the greater the number of foods offered at a meal, the greater the spontaneous intake of those foods. This finding is important because not only does it expand the concept of variety from the kinds of foods to the number of foods, but it presents an environmental variable that might contribute to overeating and obesity.



## 1. Introduction

The variety of foods available at meals has been demonstrated to have a powerful effect on the amount consumed. Meiselman, deGraaf and Lesher (2000) classified the effect of food variety on intake into three categories: (a) the variety of foods offered within a meal, *within-meal variety*, (b) the variety of foods offered between meals, *across-meal variety,* and (c) the variety of foods over a long period of time (months or years), *dietary variety*. In almost all cases, increasing the variety of foods offered increases total intake whether it is within-meal variety (Rolls, Van Duijvenvoorde, & Rolls, 1984; Rolls et al., 1981; Schutz & Pilgram, 1958), across-meals (Kramer, Lesher, & Meiselman, 2001; Meiselman et al., 2000; Rolls & de Waal, 1985; Schutz & Pilgram, 1958; Siegel & Pilgrim, 1958; Stubbs, Johnstone, Mazlan, Mbaiwa, & Ferris, 2001) or in feeding situations lasting weeks or even several months (Astrup, Larsen, & Harper, 2004; Rolls & de Waal, 1985).

In previous experimental studies on variety, the experimental manipulation has been to vary either the food offered or a sensory characteristic of the food. Variety can also be investigated by examining the number of foods offered at a meal. Astrup et al. (2004) suggested that variations in the number of foods available at a meal may help to explain why people who consume low carbohydrate diets suppress their food intake; consuming such a diet reduces the variety of foods available for consumption. Support for this idea can be found in an analysis of the Continuing Survey of Food Intakes by Individuals (CSFII) data by Kennedy, Bowman, Spence, Freedman and King (2001) who observed that people who consumed less than 30% of their calories from carbohydrate displayed approximately a 25% reduction in the variety of foods consumed as compared to people who consumed more than 55% of their calories from carbohydrate.

There is a paucity of data published on the effect of varying the number of foods simultaneously offered on ad libitum food consumption. The aim of the following two studies was to examine the effect of changing the number of foods offered at a meal on the ad libitum consumption at that meal. The first study examined the effect of providing two components of a three component meal on intake. The second study examined consumption when serving the same foods prepared either separately or cooked together and presented as a single composite food.

## 2. Study I

### 2.1. Methods

Participants were recruited through flyers, class announcements, and e-mails distributed via Cornell University listservs. Twenty-seven subjects, 18–21 years old, began the study, and fifteen males

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and four females completed it. Because the study utilized a within subject design, each subject was examined under all conditions; thus, no measurements of height and weight were taken. Participants were told that the study was about the effects of natural food enhancers on caloric intake and that the food enhancers worked with certain combinations of foods.

Prospective subjects were excluded from the study if they admitted to having any food allergies, if they were attempting to lose weight, or if they did not like the foods served in the study. Because the test meal was served at dinner, the subjects were asked to consume the same food in about the same amount prior to dinner on each day of testing. In addition, they were asked to maintain about the same level of physical activity level on each testing day. At the end of the study all subjects were debriefed. The study was approved by the Cornell University Institutional Review Board.

All meals were prepared and served as dinners in the Cornell University Human Metabolic Research Unit between the hours of 1700 and 1900. Two different meals were served. Meal 1 consisted of chicken tenders (Tyson Original Chicken Tenders), potato tots (Ore Ida Tator Tots), and green beans (Birds Eye Green Beans). Meal 2 consisted of a chicken filet (Tyson Mesquite Chicken Filets), rice (long-grain Emerald White Rice), and peas (Birds Eye Peas). The nutritional values, derived from food labels, of the foods served are displayed in Table 1. Water was always available.

The participants were randomly assigned to one of six groups at the beginning of the study. Each group was offered parts of either Meal 1 or Meal 2 consisting of (a) a composite meal (protein, carbohydrate, and vegetables), (b) a "low carb" meal (protein and vegetables), or (c) vegetarian meal (carbohydrate and vegetables). The dinners were served buffet style on Monday, Wednesday, and Friday for two consecutive weeks. Subjects ate all of their meals together on each of the six occasions. The order that the groups received the six meals was randomly determined with the provision that no two groups received the same dinner on a given night. The participants were instructed to take as much food or as little food on their plate, as well as to take second servings if desired. Each food was served on small individual plates or bowls which were weighed by a research assistant and then weighed again after they finished eating.

Data were analyzed using SPSS version 16. Statistical significance ($p<0.05$) was detected using ANOVA and paired, 2-tailed, t-tests with a Bonferonni Post-Hoc correction for multiple comparisons.

### 2.2. Results and discussion

Because ANOVA indicated no significant effect ($p=0.4$) of day of testing on total energy consumed, the data for all six testing days was combined and analyzed for main effects. Although the mean consumption weight of Meal 1 (chicken tenders, potato tots, and green beans; $489 \pm 29$ g) and Meal 2 (chicken filet, rice, and peas; $399 \pm 23$ g) were significantly different ($p<0.02$), no statistical interaction was observed between the two meals and the constituents of the meal (Composite meal [protein + starch + vegetables], "Low Carb" meal [protein + vegetables], or Vegetarian meal [starch + vegetables]) on total amount consumed. Consequently, the two meals were averaged together for the final analysis.

Fig. 1 shows the effect of eliminating the major source of carbohydrate or protein from the meal on the consumption of the remaining foods. Eliminating the major source of carbohydrates (Low Carb dinner) resulted in a significant increase in both the consumption of the source of protein ($p<0.001$) and of vegetables ($p<0.005$). Eliminating the major source of protein (Vegetarian dinner) resulted in a smaller, but significant increase in the consumption of carbohydrate ($p<0.001$), as well as an increase in the consumption of vegetables ($p<0.03$). Similar effects were observed using energy as the dependent variable. There were no statistically significant differences between the amount of protein (in grams) consumed from the Low Carb dinners and the amount of carbohydrate (in grams) consumed on the low protein dinner. However, because the energy density of the protein portion of the meal was greater than the energy density of the carbohydrate portion of the meal, the total energy consumed from the protein from the Low Carb dinner was significantly greater ($p<0.02$) than that consumed from the carbohydrate of the low protein dinner.

Fig. 2 illustrates the total amount (in grams) consumed for the three dinners. Despite the increase in intake of the other two components of the meal when either the protein or carbohydrate food was eliminated, the increase in intake was insufficient to compensate for the reduction in calories. The right portion of Fig. 2 shows that removing the carbohydrate food (Low Carb dinner) resulted in a statistically significant ($p<0.02$) energy deficit of 133 kcal when compared to the Composite dinner. Withholding the major source of protein (Vegetarian) created an energy deficit of 250 kcal ($p<0.001$) relative to the Composite dinner. Although the amount of food consumed (g) from the Vegetarian dinner was not significantly different from the amount consumed from the Low Carb dinner, the amount of energy (Kcal) derived from the Vegetarian dinner was significantly less ($p=0.01$) than that derived from the Low Carb (or Composite) dinners.

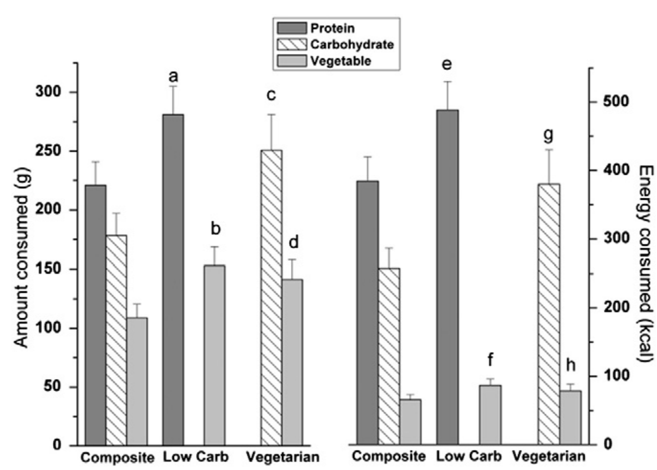


**Fig. 1.** Mean and standard deviation of the amount (grams) of the major source of protein, major source of carbohydrate, and amount of vegetables consumed from the Composite, Low Carb, and Low Protein dinners. Left panel indicates grams. The amount of protein (a) and vegetables (b) consumed from the Low Carb dinner was significantly greater ($p<0.001$ and $p<0.005$. respectively) than when the same foods were eaten from the Composite meal. Similarly, the amount of carbohydrates (c) and vegetables (d) consumed on the Low Protein meal was also significantly greater ($p<0.001$ and $p<0.001$, respectively) than the Composite diet. Differences between the amount of protein consumed on the Low Carb diet and the amount of carbohydrate consumed on the Low Protein diet were not statistically different. The right panel designates energy consumed. Similar to the amount consumed, the energy derived from eating the protein (e) and the vegetables (f) from the Low-Carb dinner was significantly greater ($p<0.001$ and $p<0.01$, respectively) than that consumed from the Composite meal. Finally, the amount of energy derived from eating the carbohydrate rich food (starch) and from the vegetables from the Low Protein meal was significantly greater ($p<0.001$ and $p<0.05$, respectively).

**Table 1**
Composition of foods offered in studies.

| Food | Serving size | Calories (kcal) | Energy density (kcal/g) | Fat (g) | Carbs (g) | Protein (g) |
|---|---|---|---|---|---|---|
| Chicken tenders | 1 piece, 91 g | 180 kcal | 1.98 | 7 g | 15 g | 15 g |
| Chicken filets | 1 patty, 78 g | 110 kcal | 1.41 | 6 g | 1 g | 13 g |
| Potato tots | 9 pieces, 86 g | 170 kcal | 1.98 | 8 g | 21 g | 1 g |
| Rice | 1/2 cup | 113 kcal | 1.17 | 0.3 g | 25.6 g | 2 g |
| Green beans | 2/3 cup, 81 g | 30 kcal | 0.37 | 0 g | 5 g | 1 g |
| Peas | 2/3 cup, 89 g | 70 kcal | 0.79 | 0 g | 12 g | 5 g |

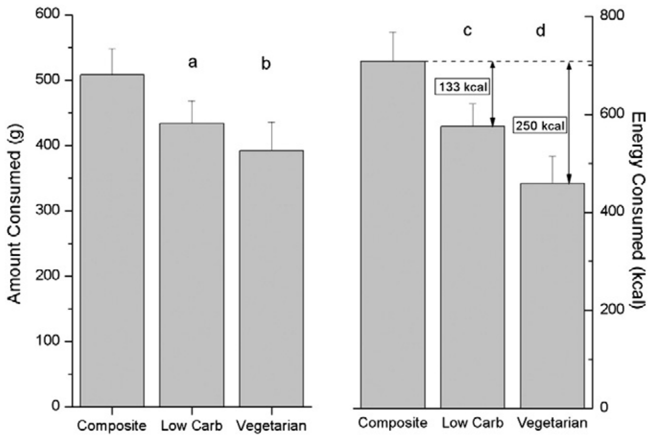


**Fig. 2.** Total amount of food and energy consumed from the Composite, Low Carb, and Low protein dinners. The left panel shows that the total amount consumed (grams) was significantly reduced on Low Carb (a) ($p<0.02$) and on the Low Protein dinner (b) ($p<0.01$). Similarly, the total energy consumed from the Low Carb dinner (c) as well as the Low Protein dinner (d) was significantly suppressed relative to the Composite dinner ($p<0.01$ and $p<0.001$, respectively).

To the best of our knowledge, these data are the first to demonstrate that reducing the number of foods offered at a meal results in a decrease in quantity consumed (g) and energy intake (kcal). This lack of energetic compensation for the reduction in the number of foods offered at meals is consistent with behavior observed in other kinds of energetic challenges; humans repeatedly demonstrate the inability to accurately regulate caloric intake (Levitsky, 2002, 2005).

This study demonstrated that removing either the major source of protein or carbohydrate from a meal resulted in a decrease in total food consumed, suggesting that the reduction was not macronutrient specific, but related to whether or not the food was present. A greater energy deficit occurred when the major source of protein was eliminated (250 kcal) than when the major source of carbohydrate was eliminated (133 kcal), likely due to the energy density of the eliminated food (meat) being greater than the energy density of carbohydrate.

It is worth noting that the magnitude of the decrease in energy consumed when the major source of carbohydrate was removed from the diet was about 18% (reduction from about 700 kcal to 575 kcal). This degree of suppression of energy intake is about the same as that observed when humans are maintained, ad libitum, on a very low carbohydrate diet for six months (19% suppression; 1600 kcal to 1300 kcal/day) (Brehm, Seeley, Daniels, & D'Alessio, 2003).

This study showed that decreasing the number of foods served at a meal decreases the total amount of food consumed at that meal. However, decreasing the number of foods offered at a meal changes the nutrient composition of the meal. It is possible that the reduction in consumption observed in the present study was due to a change in the composition of the meal rather than the number of foods offered. The purpose of the second study was to test the effect of offering the same foods either individually or as a composite food.

## 3. Study II

### 3.1. Methods

As in Study 1, subjects were recruited through flyers, class announcements, and e-mails distributed via Cornell University listservs. Twenty-four volunteers (4 males and 20 females), ages 18–21 years, entered the study. Six were excluded because they did not complete all testing periods. All participants were within the normal range of BMI ($18<BMI<25$). Similarly to the previous study, the criterion for removing subjects was: (a) any food allergies, (b) attempting to lose weight, or (c) did not like the foods served in the study.

Unlike Study 1, the experimental meal was offered at lunch. Participants were asked to eat the same breakfast at the same time of day each time they were tested and not to eat any additional food before testing. They were also asked to maintain a consistent activity level on the day prior to and the day of testing. Subjects selected one of 4 week days to eat lunch in the Cornell Human Metabolic Research Unit at the same time on four consecutive weeks. The study was approved by the Cornell University Institutional Review Board.

All foods were prepared and served in the Cornell University Human Metabolic Research Unit. The foods were served either as a composite meal (stir-fry or pasta) or as individually prepared foods. The individual ingredients of the stir-fry consisted of: onions, corn, carrots, peas, and broccoli. The pasta meal was composed of onions, celery, tomatoes, penne pasta and cauliflower. When served separately, the individual foods were prepared in a similar fashion to the composite meal, i.e., the stir-fry ingredients were individually stir-fried and the pasta ingredients were individually heated or boiled. At the end of the meal, the participants rated the acceptability of the individual foods and the meals on a 9 point scale.

Participants were assigned to one of four groups according to which day of the week they attended (Monday through Thursday). Table 2 shows the testing sequence for the study. A within subject design was used where all four meals were tested in the same week. Only one sequence was used; meals were rotated according to a Latin square.

The meal was served between the hours of 1200 and 1330. All subjects ate together in a dining area. The subjects were instructed to take as much or as little of the foods offered at the food table. They were instructed to place the food into a separate small paper plate or bowl then to take their food to a weighing table where a staff member weighed the items. After eating, the subjects were asked to return their food trays to the weighing table for a second weight measurement. The subjects were also told that they could return to the food table for more food if they desired and repeat the weighing procedure. Water, salt, pepper and garlic powder were freely available.

The data were analyzed using SPSS software version 16. Statistical significance ($p<0.05$) was determined using ANOVA and paired, 2-tailed, t-tests with a Bonferonni Post-Hoc correction for repeated tests.

### 3.2. Results and discussion

All data were analyzed using both grams consumed and calories consumed. Results did not differ depending upon the dependent variable unit used; only grams consumed will be presented. ANOVA indicated that the main effect of day of the week, the main effect of week, and an interaction between day and week and the amount consumed were not statistically significant ($p=0.2$). Therefore, the data were collapsed to allow paired comparisons between the meals served as separate foods or as a composite meal. Results are presented in Fig. 3. Significantly more of the pasta meal was consumed than the stir-fry in both separate and composite conditions ($p<0.03$). However, no significant interaction was found between the type of meal (pasta vs. stir

**Table 2**
Sequence of meal testing.

| | Monday group | Tuesday group | Wednesday group | Friday group |
|---|---|---|---|---|
| Week 1 | A | B | C | D |
| Week 2 | B | C | D | A |
| Week 3 | C | D | A | B |
| Week 4 | D | A | B | C |

A = Stir-fry ingredients served separately.
B = Pasta ingredients served as a composite meal.
C = Stir-fry ingredients served as a composite meal.
D = Pasta ingredients served separately.

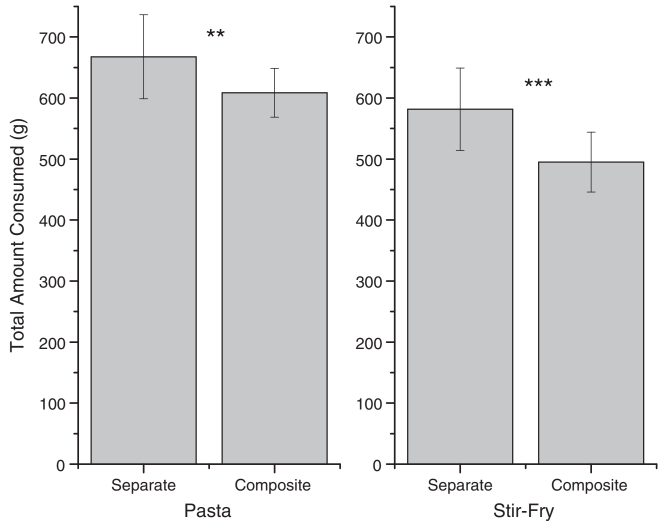


**Fig. 3.** Mean and standard deviation of the total amount of foods consumed from the Stir-Fry and Pasta Meal and the average of the sum of the individual foods that constituted the composite meals when they were consumed separately. **$p<0.025$; ***p<pasta<0.01.

fry) and whether the meal was served as individual ingredients or as a composite meal ($p>0.1$).

Serving foods separately resulted in a greater total intake than when the foods were prepared and served as a composite meal. As illustrated by Fig. 3, consumption of the individual foods that constituted the pasta meal was significantly greater than consumption of the composite pasta meal ($p<0.02$). This relationship was observed again with the stir-fry; the sum of the individual foods consumed was greater than when they were combined into the composite meal ($p<0.03$).

Fig. 4 depicts the results of the acceptability ratings. Although not statistically significant, the acceptability rating of both composite meals was significantly greater than the mean acceptability rating of the individual foods.

The results of Study 2 confirm and extend the effects observed in Study 1: increasing the number of foods offered at a meal caused greater total food consumption. The results further suggest that the increase in the intake observed in Study 1, where three foods were presented compared to two, was not due to a difference in the nutritional composition of the different meals. Indeed, the nutritional composition of the sum of the individual foods combined was approximately the same as the composite meals. Rather the increased intake of the individual foods relative to the single composite meal was more likely to be related to the number of foods simultaneously presented than the nutritional composition of the foods.

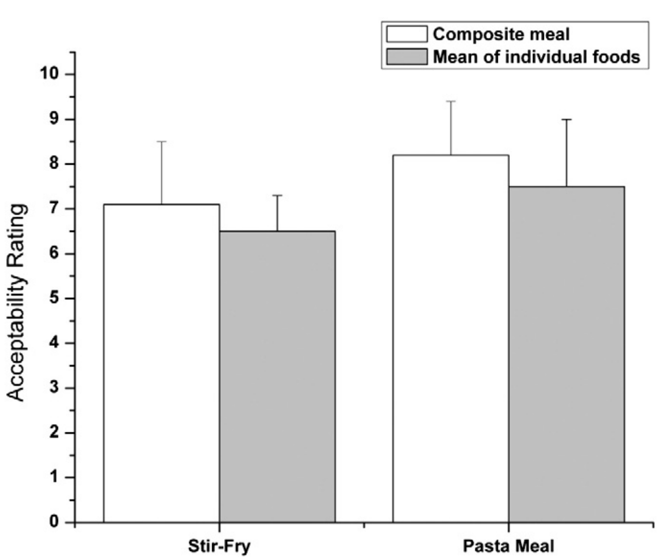


**Fig. 4.** Mean and standard deviation of the acceptability ratings for the Stir-Fry and Pasta Meal and when the individual foods constituted the composite meals. The rating scale ranged from 1 to 9.

These results add to a growing body of evidence of the powerful effect that a variety of foods plays in determining intake (Raynor & Epstein, 2001; Remick, Polivy, & Pliner, 2009). Whereas previous studies have examined the effect of variety within a meal by examining sequential presentations of foods, the present studies add to our understanding of the effects of variety by demonstrating that the effects can also be observed when different foods are offered simultaneously.

A common explanation for the reduction in food intake when the same foods are offered sequentially is stimulus specific satiety (Raynor & Epstein, 2001; Rolls, Hetherington, & Burley, 1988). Offering the same foods sequentially causes a reduction in food intake much like habituation which has been proposed to explain stimulus specific satiety (Raynor & Epstein, 2001). However, when, during a sequence of offering the same food, a different food is offered (changing the stimulus) food intake is increased (Meiselman et al., 2000; Stubbs et al., 2001) rather than depressed. In the present studies, the increased food intake was not caused by introducing different foods. Rather, the increased intake was caused by the presence of a greater number of different foods on the plate. Thus, it appears unlikely that habituation can account for the present phenomenon. Rather, the increased intake was probably caused by the presentation of more food.

The variety effect observed in the present study is similar to an older concept called "stimulus bound eating." This refers to the condition where stimuli associated with food (sight, smell, etc.) are sufficient to elicit consumption (Valenstein & Cox, 1970). The greater the number of different food stimuli presented, the greater is the total food intake (to a point). Indeed, as demonstrated recently by the studies of television advertising, viewing food commercials actually stimulates eating behavior relative to watching non-food commercials (Halford, Boyland, Hughes, Oliveira, & Dovey, 2007; Halford, Gillespie, Brown, Pontin, & Dovey, 2004; Harris, Bargh, & Brownell, 2009). It is possible that food stimuli may act as "priming" signals that operate by stimulating food intake.

The results from these two studies may explain two widely observed, yet unrelated, findings. First, as suggested by Astrup et al. (2004), number of foods presented may be the reason why low carbohydrate diets cause a reduction in food intake (Kennedy et al., 2001). The results from the present study complement this idea by demonstrating that a reduction in the number of foods offered significantly reduces the amount consumed. Second, the results may also help explain why vegetarians have a lower energy intake than non-vegetarians (Freedman, King, & Kennedy, 2001; Haddad & Tanzman, 2003) and why people who change from an omnivorous to a vegetarian diet reduce their energy intake (Delgado, Gutierrez, Cano, & Castillo, 1996; Phillips, Hackett, Stratton, & Billington, 2004). Because the average energy density of vegetables is lower than the energy density of meat or meat products, replacing meat with an equal volume of vegetables will result in a reduction in the amount of energy consumed. Humans do not respond to a reduction in the energy density of foods by increasing the amount they consume (Bell, Castellanos, Pelkman, Thorwart, & Rolls, 1998; Levitsky, 2008).

There are several possible limitations of the present studies. First, only two different meals were examined in Study 1 and 2. It is possible that other combinations of protein, carbohydrates and vegetables may produce a different pattern of results than shown by Study 1. However the high degree of similarity (lack of statistically significant interactions) between the two meals tested in each study suggests that the results will generalize to other meals. Second, the variation in the number of food items manipulated in Study 1 was between two and three items. It is possible that more precise compensation would have occurred if a greater range of values were chosen. Third, it is possible that the effect observed in Study 2 may be restricted to ad libitum consumption from a buffet style served meal. Perhaps putting the different foods on the participant's plates may produce results that would differ from what was observed in these studies. A fourth limitation of both studies is that the subjects were young college students and not representative of the population. However, regulation of energy intake appears to be more precise in younger populations than in older populations (Sawaya et al., 2001). Finally, the participants in these studies were tested under each condition only once. It is possible that if subjects were repeatedly provided with a reduced number of foods at a meal, they would eventually increase their intake and the reduction in energy consumption would disappear.

On the other hand, strengths of these studies allow for reasonably sound conclusions. First, the studies were conducted within subjects; each subject underwent all treatments. Such a procedure eliminates much of the between subject variability and reduces the necessity to control for gender, age, BMI, and other possible confounds. Second, no attempt was made to control food consumed outside the laboratory other than the recommendation that the subjects maintain the same level intake and activity level. This lack of control would be expected to reduce the possibility of finding a significant effect of the different experimental treatments. Moreover, subjects ate together, reducing the possibility of finding a treatment effect. Finding statistically significant effects under these conditions, which are more akin to “real life” situations, suggest that the effect is sufficiently powerful to be biologically meaningful.

The number of different food products introduced into the American market place has increased significantly from about 1300 products in 1970 to about 20,000 in 1996 (Gallo, 1997). If the increase in the number of food items sold translates into an increase in the number of products served, then the effect of offering a greater number of different foods at a meal may be similar to the effects of other environmental variables, constituting a significant increase in the amount consumed. Such variables include the energy density of the diet (Levitsky, 2008) portion size (Diliberti, Bordi, Conklin, Roe, & Rolls, 2004; Levitsky & Youn, 2004; Rolls, Roe, Kral, Meengs, & Wall, 2004), and social facilitation (Clendenen, Herman, & Polivy, 1994; De Castro, 1995). These variables exert a small, yet persistent, effect on human eating behavior and may be, in part, responsible for the increase in body weight prevalent today.

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**Contributors**

Authors DAL and SI designed and carried out the first study. DAL and CP statistically analyzed the results and wrote the manuscript.

**Conflict of interest**

None of the authors had any financial or personal interests in the outcome of the study.

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