Effect of Number of Food Pieces on Food Selection and Consumption in Animals and Humans

by

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ABSTRACT

There are several visual dimensions of food that can affect food intake, example portion size, color, and variety. This dissertation elucidates the effect of number of pieces of food on preference and amount of food consumed in humans and motivation for food in animals. Chapter 2 Experiment 1 showed that rats preferred and also ran faster for multiple pieces (30, 10 mg pellets) than an equicaloric, single piece of food (300 mg) showing that multiple pieces of food are more rewarding than a single piece. Chapter 2 Experiment 2 showed that rats preferred a 30-pellet food portion clustered together rather than scattered. Preference and motivation for clustered food pieces may be interpreted based on the optimal foraging theory that animals prefer foods that can maximize energy gain and minimize the risk of predation. Chapter 3 Experiment 1 showed that college students preferred and ate less of a multiple-piece than a single-piece portion and also ate less in a test meal following the multiple-piece than single-piece portion. Chapter 3 Experiment 2 replicated the results in Experiment 1 and used a bagel instead of chicken. Chapter 4 showed that college students given a five-piece chicken portion scattered on a plate ate less in a meal and in a subsequent test meal than those given the same portion clustered together. This is consistent with the hypothesis that multiple pieces of food may appear like more food because they take up a larger surface area than a single-piece portion. All together, these studies show that number and surface area occupied by food pieces are important visual cues determining food choice in animals and both food choice and intake in humans.

DEDICATION

I dedicate this dissertation to my wonderful husband, Rajat M. Wadhera who always encouraged and motivated me to pursue my dreams, who gave me endless love and support, who comforted me when I was down, and was always there to make me laugh through the various trials and tribulations of my life. This dissertation is also dedicated to both my parents (Nisha Bajaj and Prakash Bajaj) and parents-in-law (Sanjiv Wadhera and Rekha Wadhera) for their endless love, support, prayers, and blessing throughout this rigorous process. I would also like to recognize my brother Kunal Bajaj who encouraged me to pursue this field of study and my beautiful sister-in-law, Beata Bajaj for teaching me about patience and appreciation. I also want to dedicate this dissertation to my wonderful nephews Karan and Aggasthya for giving me their selfless love and inspiration to pick myself up and move ahead. Lastly, I dedicate this dissertation to my sister Kavina Bajaj for her eternal love, support, kindness, and appreciation.

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TABLE OF CONTENTS

CHAPTER Page

CHAPTER Page

CHAPTER Page

CHAPTER Page

LIST OF TABLES

LIST OF FIGURES

Figure Page

CHAPTER 1

INTRODUCTION

Energy intake varies widely from day to day. This variance in energy intake is regulated by the body's homeostatic system. The body's homeostatic processes trigger an increase in food intake when food deprived. According to James Neel (1962), an American geneticist, this hyperphagic response to food depletion, may be an adaptive response to protect the organism from starvation in the natural environment.

Although internal cues produced by hunger and satiety can initiate food intake, evidence suggests that daily energy intake is not tightly controlled by the body's homeostatic processes. For example, Levistky (2005) argued that if food intake is dependent on homeostatic processes only, then humans would simply eat when hungry, and not when full. However, several studies show that satiated humans and animals will begin eating if given unlimited access to palatable foods (Faith et al., 2006; Fisher & Birch, 2002; Hill et al., 2008). He also pointed out that if daily energy intake is heavily influenced by physiological processes, then changes in daily energy intake should adjust to compensate for any excess or shortage of calories consumed. But, several studies showed that subjects fail to compensate for an energy deficit from skipped meals or energy surplus from additional meals (Berkey, Rockett, Gillman, Field, & Colditz, 2003; Cho, Dietrich, Brown, Clark, & Block, 2003; Nicklas, Bao, Webber, & Berenson, 1993; Schlundt, Hill, Sbrocco, Pope-Cordle, & Sharp, 1992). Of course these studies do not indicate that physiological processes have no influence on food intake, but rather that as long as food is available in the environment, hunger and satiety signals are easily overridden and intake influenced by both environmental cues and learned eating patterns.

When food is available, food consumption may occur in response to several environmental (external) cues. These environmental cues include those that are directly related to the food (i.e. the “food environment”) or indirectly related to food, but associated with eating (i.e. the “eating environment”) (Wansink, 2004). Cues in the eating environment such as lighting, sound, the time of day, and the presence of others can affect food intake. For example, dull or no lighting and soft music were shown to *decrease* food intake (Gal et al., 2007 in Spence, Harrar, & Piqueras-Fiszman, 2012; Ross, 1970 in Linne, Barkeling, Rossner, & Rooth, 2002; Wansink, 2004) whereas, social and media distractions and eating later in the day were shown to *increase* food intake (de Castro, 1990, 1994, 2004; Herman, Roth, & Polivy, 2003). Cues directly related to the food such as portion size, palatability, and presence of variety of foods can also affect food intake. People eat more when given larger than smaller portions (Ello-Martin, Ledikwe, & B.J. Rolls, 2005; B.J. Rolls, 2003), palatable than unpalatable foods (Bobroff, & Kisileff, 1986; de Castro, Bellisle, & Dalix, 2000; Wansink & Park, 2001; Zandstra, de Graaf, Mela, & Staveren, 2000) and varied than monotonous foods or flavors (McCrory et al., 1999; see Remnick, Polivy, & Pliner, 2009 for review).

Identifying the various external factors affecting food intake can elucidate potential targets for the treatment of obesity. Obesity is a medical condition involving the excess accumulation of body fat caused by an increase in energy intake or a decrease in energy expenditure. Elevated body fat levels in turn, can adversely affect health and increase the risk for life-threatening conditions such as diabetes, cardiovascular disease, and cancer (Calle, & Kaaks, 2004; Kahn, Hull, & Utzschneider, 2006; Poirier et al., 2006). According to the World Health Organization, about 1.4 billion people were overweight and nearly 500 million people were obese in 2008. In the United States alone, about 35% of adults and 17% of children were obese from 2009 to 2010 (Ogden, Carroll, Kit, & Flegal, 2012). If the current trends in obesity continue, it is expected that almost half the American population will become obese by 2030 (Finkelstein et al., 2012). Since physical activity levels have remained largely unchanged in the past two decades (Bleich, Cutler, Murray, & Adams, 2007; Finkelstein, Ruhm, & Kosa, 2005), increased energy intake has been identified as the potential driver of the obesity epidemic.

Although several external cues associated with food can affect energy intake, the focus of this dissertation is on cues directly related to food. Several sensory cues from a food can affect food intake such as appearance, taste, texture, smell, and temperature (Brown, 2011; Imram, 1999). Although many people cite taste as the most important factor affecting their food intake (Glanz, Basil, Maibach, Goldberg, & Snyder, 1998) in many cases the first sensory contact with food is through the eyes.

There are several visual cues that can affect food intake but one potent visual cue shown to augment food intake is portion size. Marketplace and restaurant portions are two to five times larger now than in the past (Nielsen & Popkin, 2003). Large portions of food encourage greater food consumption leading to an increase in caloric intake. For instance, when snack foods, beverages, sandwiches, and pasta portions were increased in size, energy intake also increased in both children and adults (Fisher & Kral, 2008; Levitsky & Youn, 2004; B.J. Rolls, Morris, & Roe, 2002; B.J. Rolls, Roe, Kral, Meengs,

& Wall, 2004a; B.J. Rolls, Roe, & Meengs, 2006a, 2006b, 2012; B.J. Rolls, Roe, Meengs, & Wall, 2004b).

There are two hypothesized mechanisms by which large portion sizes of foods lead to increased energy intake. First, portion sizes of foods can serve as visual cues or "benchmarks" to determine the amount of food to consume (Wansink & Van Ittersum, 2007). When visual input was absent, diners were unable to monitor how much food was consumed, resulting in an increase in energy intake from larger than smaller food portions (Scheibehenne, Todd, & Wansink, 2010).

Second, portion sizes serve as visual references for determining the size of bites taken from them (Fisher & Kral, 2008; Fisher, B.J. Rolls, & Birch, 2003). Larger bites are taken from larger portions of food only when the visual cue of the portion is present. For example, Burger, Fisher, and Johnson (2011a) found that blindfolded subjects took smaller bites from large portions of food than sighted subjects showing that visual cue of the large food portion can change the microstructure of eating. Taking large bites from food was shown to increase energy intake by facilitating gorging. Gorging shortens the amount of time that the food is present in the mouth resulting in shorter orosensory exposure time which in turn results in reduced feelings of fullness, increased desire to eat, and increased energy intake (de Wijk, Zijlstra, Mars, de Graaf, & Prinz, 2008; Kissileff, Zimmerli, Torres, Devlin, & Walsh, 2008; Kral, Buckley, Kissileff, and Schaffner, 2001; Weijzen, Smeets, & de Graaf, 2009; Zijlstra, de Wijk, Mars, Stafleu, & de Graaf, 2009). Moreover, taking large bites facilitate overeating by accelerating eating rates (Scisco, Muth, Dong, & Hoover, 2011; Spiegel, Kaplan, Tomassini, & Stellar, 1993). Eating fast does not allow sufficient time for the development of satiation signals leading to reduced feelings of satiation and increased energy intake (Azrin, Kellen, Brooks, Ehle, & Vinas, 2008; Burger et al., 2011b; Ferster, Nurnberger, & Levitt, 1962; Forde, van Kuijk, Thaler, de Graaf, & Martin, 2013b; Kissileff et al., 2008; Martin et al., 2007; Melanson, 2004; Spiegel, 2000; Spiegel & Jordan, 1978; Zjilstra, Mars, de Wijk, Westerterp-Plantenga, & de Graaf, 2008). Therefore, large food portions can change eating behavior, which can ultimately affect the amount of food consumed.

The size of silverware, dinnerware, and commercial food packages also influences food intake (Sobal & Wansink, 2007; Wansink, 1996). Subjects served themselves 50% more ice-cream when given a large serving spoon and bowl and ate more ice-cream than those given a smaller serving spoon and bowl (Wansink, Van Ittersum, & Painter, 2006). Similarly, subjects ate more from a one-gallon bowl of snacks than those given two, half-gallon bowls of snacks (Wansink & Cheney, 2005) and more popcorn when served in larger than smaller containers (Wansink, & Kim, 2005). Also, sizes of eating utensils indirectly influence feeding behaviors, which can ultimately affect food intake. Lawless, Bender, Oman, and Pelletier (2003) showed that subjects took larger sips from liquids served in larger than smaller cups. Taking larger mouthfuls from food shortens orosensory exposure resulting in reduced feelings of fullness and increased energy intake as mentioned previously (de Wijk et al., 2008; Kissileff et al., 2008; Kral et al., 2001; Weijzen et al., 2009; Zjilstra et al., 2008; Zijlstra et al., 2009).

The sizes of eating utensils also serve as visual references to determine further food intake. For example, people use the emptying of a bowl or plate as a visual cue to terminate food intake. Wansink, Painter, and North (2005) randomly assigned subjects to receive a regular bowl or "self-refilling" bowl of soup. The self-refilling bowl would refill automatically as the soup was ingested so that subjects never saw an empty bowl. The results showed that subjects given the self-refilling bowl ate 70% more soup and indicated no greater satiation than those given the regular bowl. The authors suggested that without the visual cue of the empty bowl, subjects were unable to rely on their own feelings of fullness to terminate eating before too much food was consumed.

One reason that subjects overconsume food from large eating utensils is because of susceptibility to visual illusions. For example, a tall, narrow glass is perceived to contain more liquid than a short, wide glass of equal volume because both children and adults tend to focus on the height of the object to make quantitative estimations, while ignoring the rest, a tendency called centration bias (Anderson & Cuneo, 1978, Raghubir & Krishna, 1999). This bias ultimately affects the amount of food served and consumed. For example, Wansink and Van Ittersum (2003a) found that both adolescents and adults poured more juice in short, wide glasses than tall, narrow ones. In addition, Raghubir and Krishna (1999) found that the overestimation of liquids served in taller glasses resulted in lower perceived volume consumption, higher actual consumption, lower post-consumption satisfaction, and consequently more requests for refills than liquids served in short, wide glasses. The authors hypothesized that when a subjects' expectations (i.e. the liquid in tall glass was overestimated) do not match actual volume consumed, subjects consume more to compensate for the perceived lower volume consumed (Raghubir & Krishna, 1999).

When food is served on plates, people tend to focus on the diameter of the plate to determine food amounts. For example, five- to-six-year-old children correctly guessed which portion of food was larger only when the larger portion was served on a larger plate and when the large food portion was spread to double the diameter of the smaller food portion (Fisher & Kral, 2008). Children also perceived a portion of food spread out on a larger area on a plate as more food than the same portion of food spread out to a smaller area, even though plate size was held constant (Fisher & Kral, 2008).

One explanation for incorrect estimations of food based on the *spread* of the food portion may be explained by the Delbouef illusion. Food served on larger plates or bowls may be displaced away from the edge of the plate, resulting in a significant underestimation of food (called contrast effects) and foods served on smaller plates or bowls displace to the edges, resulting in a significant overestimation of food (called assimilation) (Van Ittersum & Wansink, 2011). These assimilation and contrast effects are together coined the Delbouef illusion. This visual illusion occurs when the presence of one circle changes the perceived size of another circle, in this case the spread of the food portion relative to the plate or bowl in which the food is served (Nicolas, 1995). This visual illusion consequently affects quantity estimations and the amount of food served and consumed. For example, Van Ittersum and Wansink (2011) found that subjects poured less soup into a smaller than larger bowl due to overestimation of the diameter of the smaller bowl. Consequently, this overestimation of foods in smaller bowls, may also explain the underserving of food in smaller than larger bowls (Van Ittersum & Wansink, 2011; Wansink et al., 2006b).

Other visual cues related to a portion of food can also affect food intake. For example, rearranging the ingredients of a portion of food can also affect food intake. Levistky, Iyer, and Pacanowski (2012) presented the ingredients of a vegetable-stir fry and pasta portion either separately or mixed together. When the ingredients were presented separately subjects ate more than when the ingredients were mixed together. The authors suggested that segregating a food portion into discrete units increases energy intake by increasing the perceived variety of foods available for consumption.

In addition to changing the appearance of a food portion, cutting up foods into varied sizes and numbers can also affect quantity estimations and the amount of food consumed. Nisbett and Storms (1972), varied the size and number of food pieces and found that subjects ate more when given four, quartered sandwiches (16 pieces) than the same sandwiches cut into 32 bite-sized pieces. The authors hypothesized that quartered sandwiches may have resembled "meals" that are typically eaten in large amounts, whereas, bite-sized pieces may have resembled "snacks" that are typically eaten in smaller amounts. Similarly, Marchiori and colleagues (2011) found that adults ate more when 10 large candies were served, than the same candies cut into 20 bite-sized pieces (Marchiori, Waroquier, & Klein, 2011). In a subsequent study they found that children ate more when 18 large cookies were served than those cut into 36 bite-sized pieces (Marchiori, Waroquier, & Klein, 2012). In addition, Weijzen, Liem, Zandstra, and de Graaf (2008) found that subjects ate more when given six large candy bars than those cut into 66 bite-sized pieces.

In the aforementioned studies, however, size of pieces varied along with the number of food pieces as the total amount of food in the portion was held constant. The portion with the smaller pieces also contained a greater number of pieces than the portion with the larger food pieces, i.e., 16 large sandwich pieces were cut into 32 bite-sized ones (Nisbett & Storms, 1972), 10 large candy were cut into 20 small pieces (Marchiori et al., 2011), 18 large cookies were cut into 36 small pieces (Marchiori, et al., 2012), and six chocolate bars were presented as 66 candy pieces (Weijzen et al., 2008). In this dissertation I was interested in whether the number of food pieces, independent of size, may be an important visual cue from food portions affecting intake which has largely been overlooked in the literature.

To this date, the effects of number of pieces, independent of size, have been studied exclusively in animals. Animals ran faster for multiple pieces than an equicaloric, single piece of food (Amsel, Hug, & Surridge, 1968; Campbell, Batsche, & Batsche, 1972; McCain, 1969; Traupmann, 1971; Wolfe & Kaplon, 1941) showing that animals find several pieces of food to be more rewarding than an equicaloric, single piece of food. Multiple pieces of food are also preferred over an equicaloric, single piece of food (E.J. Capaldi, Miller, & Alptekin 1989) showing that multiple pieces of food are more rewarding than a single piece in animals.

Unanswered Questions

Some studies showed that animals find multiple pieces of food to be more rewarding than a single piece, but no study has investigated the effects of number of food pieces on both preference and running speed together in a single study. Therefore, the purpose of Chapter 2 is to measure the effects of number of food pieces on both preference and running speed in rats and to propose and test an interpretation of the effect.

In humans, varying the size and number of food pieces together has been shown to affect food intake. Both children and adults ate more when given larger than smaller food pieces (Marchiori et al., 2011; Marchiori et al., 2012; Nisbett & Storms, 1972). The authors hypothesized that decreasing the size of food units decreases the amount of food considered appropriate to eat, resulting in lower food intake. But, in addition to size, the number of food pieces also varied in the aforementioned studies. Reducing the size of cookies simultaneously resulted in a larger number of pieces i.e. 16 large sandwiches were cut into 32 small pieces (Nisbett & Storms, 1972), 10 large candies were cut into 20 small pieces (Marchiori et al., 2011), and 18 large cookies were cut into 36 bite-sized pieces (Marchiori et al., 2012). Perhaps, then the number of food pieces is an important visual cue affecting food intake. No study has investigated the effects of number of pieces of food (independent of size) on preference and energy intake in humans. Therefore the purpose of Chapter 3 is to measure the effects of number of food pieces on preference and amount of food consumed in humans.

Studies on quantity estimations of foods served on plates, bowls, and glasses have only used amorphous foods i.e., foods that take up the shape of the container such as macaroni and cheese (Fisher & Kral, 2008), cereals (Van Ittersum & Wansink, 2011) soup (Van Ittersum & Wansink, 2011), ice-cream (Wansink et al., 2006b), and beverages (Raghubir & Krishna, 1999; Wansink & Van Ittersum, 2003a). Only one previous study has measured the effects of the spread of food on a plate (Fisher & Kral, 2008), and that used amorphous foods. Therefore, Chapter 4 will address the effects of surface area occupied by a non-amorphous food (i.e. a food cut into discrete number of pieces) on energy intake in humans.

CHAPTER 2

EFFECTS OF NUMBER AND SURFACE AREA OCCUPIED BY FOOD PIECES ON PREFERENCE AND RUNNING SPEED IN RATS

Early studies investigating the rate of learning in animals focused on the amount of reward as an incentive for learning (Reynolds & Pavlik, 1960). Grindley (1929) found that chickens ran faster for multiple (two to six) rice grains than one rice grain, showing that the rate of learning in animals is dependent on the amount of reward. However, the authors hypothesized that the number of units of food were also greater in the multiple-rice grain portion than the single rice grain. Therefore, to distinguish between number of food units and the amount of reward on learning, Wolfe and Kaplon (1941) compared the running speeds of chickens for one large popcorn, 1/4th piece of popcorn, or four pieces of popcorn. They found that chickens ran fastest for the four-piece popcorn followed by those who got the single, intact popcorn, and lastly those that got the 1/4th piece, showing that number of pieces may be a better incentive than amount of reward as an incentive for learning.

One study compared the effectiveness of rewards varying in magnitude and number by comparing the effects of reductions in amount and number of units of a food on runway performance in rats (Daly, 1972). The author found that rats given a large food pellet in acquisition ran slower when shifted to a small pellet than those given a small pellet reward in acquisition. However, rats given 25 small pellets in acquisition ran slower when shifted to one small pellet than those given a large pellet in acquisition. Therefore, reductions in number of units of food elicited greater depression of response than reductions in the amount of reward, showing that multiple food units are more rewarding than a single food unit. In addition, Campbell et al (1972) found that rats ran significantly faster for 22, 45 mg pellets than those given a single, 1000 mg pellet and Traupmann (1971) found that rats ran significantly faster for 11, 45 mg pellets than a single, 500 mg pellet.

Rats also prefer multiple pieces of food over a single piece. E.J. Capaldi et al (1989) trained rats to receive a single, 300 mg pellet in one arm and four, 75 mg pellets in the alternative arm on a T-maze. The results showed that rats preferred the arm containing four, 75 mg pellets (totaling 300 mg), over another arm containing an equicaloric, single food pellet. Although multiple pellets of food have been shown to be more rewarding than a single, large piece of food, both running speed and preference for a multiple- or single-piece food were not measured together in a single study. This is important so that we can test if running speed differs as a function of preference for the reward.

The purpose of Experiment 1, therefore, was to replicate the findings of E.J. Capaldi et al (1989) and also investigate *both* preference and running speed of rats trained to associate one T-maze arm with multiple pieces of food (30, 10 mg pellets totaling 300 mg) and another with an equicaloric, single pellet of food (300 mg). We hypothesized that if a multiple-pellet food is more rewarding than a single pellet, then rats will prefer and also run faster for the arm containing 30, 10 mg food pellets than one containing a single, 300 mg food pellet.

Experiment 1

Method

Subjects. Subjects were 39 experimentally-naive, male, Sprague-Dawley rats from Harlan Co., Indianapolis, IN. One rat failed to complete the training trials and was therefore removed from the experiment. Rats were 85 days old upon arrival and 92 days old upon start of deprivation. Animals were single-housed, given food and water ad libitum, and were maintained on a 12-h light/dark cycle. Experimental procedures were approved by the Arizona State University Institutional Animal Care and Use Committee and adhered to Guidelines for the Care and Use of Laboratory Animals.

Materials. 10 mg (many condition) and 300 mg (one condition) Noyes Precision Pellets purchased from Test Diet (Richmond, Indiana) were used for this study.

Apparatus. A T-Maze purchased from Columbus Instruments was used. The stem of the maze was 61 cm long from the start box (located at the base of the stem) to the choice area (at the intersection of the T). The start box was approximately 16.5 cm long and the length of each arm of the T-maze was 45.7 cm. The entire maze was covered by transparent, plastic lids. Metal inserts separated the stem of the maze from the start box (guillotine door) and the arms of the maze. See Figure 1 for a diagram of the T-maze used in the experiment.

The entire maze was set up with six, invisible, infrared beams connected to a computer that recorded the time (in milliseconds) that the beams were interrupted when the rats crossed the area. Each arm of the maze contained two beams which were 25.5 cm apart and the stem of the T-maze contained two beams which were about 49.5 cm apart. A beam break was recorded automatically when the rat disrupted an infrared beam by movement and a beam make was recorded when the rat crossed the beam completely. Therefore, the series of beam breaks and beam makes were used to calculate the time taken by rats to move from one area of the maze to the other.

Food was placed at the end of each arm. The type of food placed in each arm depended on whether rats received the multiple or single pellet of food in that arm. Animals on entering the arm were confined there by lowering the metal insert. They were removed from the maze once the trial was completed by lifting the clear, plastic lid.

Procedure. The procedure was similar to E.J. Capaldi and colleagues (1989). On arrival at the laboratory, animals were placed on adaptation for a week and ad lib weights taken for three days. Ad lib water was present throughout the experiment in clear plastic bottles mounted on the right of the food hopper in the front of each cage. Following one week of adaptation, on Day 1, all food was removed from the cages. On Days 2-15, all rats were fed 14 g of food each day at 9:00 a.m., restricting their weights to 85% of their free-feeding body weight. On Day 15, each rat got both a 300 mg pellet and 30, 10 mg pellets in their home cage. Once rats sampled the pellets, one 300 mg pellet and 30, 10 mg pellets were then placed in the arms of the maze for the rats to explore and habituate to the maze. Half the rats had 30, 10 mg pellets in the left arm and the single 300 mg pellet in the right arm, and the other half received the reverse.

Training. On Day 1 of training, rats were brought into the experimental maze room in squads of two and received one free (F) and one forced (FO) trial. On a F trial, both arms were open and rat could enter either arm. On a FO trial, rats were forced into the arm it did not enter in the free trial, by blocking the previously entered arm with a metal insert. Each rat received Trial 1 before the next rat received Trial 2. Once a rat was placed in the start box, the trial began by raising the guillotine door three seconds later. On Days 2-7 of training, rats received four trials each, two F and two FO trials. The order of the F and FO trials was counterbalanced across days in an ABBA fashion. Therefore, on A days, half the rats received a F, F, FO, FO order of trials and the other half received F, FO, F, FO order. On B days, half the rats received F, FO, F, FO and the other half received the opposite, with an inter-trial interval of 2 min. The rat's arm choice on each free trial was recorded. Five min after the last trial of the day, rats received food in their home cage.

Testing. Rats received three days of Testing. On each testing day, they received four free trials. Arm entry on all free trials was recorded. Five minutes after the last trial of the day, the rats were fed 14 g of food in their home cage.

Data analyses. Total number of multiple and single-pellet choices were counted across all free trials in training. A between-within, repeated measures ANOVA was then conducted on all free trials with counterbalancing (left arm/30 pellets vs. right arm/ 30 pellets) as a between-subjects factor and food choice (30 vs. one pellet), and days as within-subject factors. Similarly, a between-within repeated measures ANOVA was conducted on all three days in testing with food choice (30 vs. one pellet), and days as within-subject factors and counterbalancing (left arm/30 pellets vs. right arm/30 pellets) as a between-subjects factor.

Running speeds (cm/sec) were calculated using average time (sec) and distance (cm) from the start box to the end of the goal arm (where the food was located) and from the beginning to the end of the goal arm for each food choice in testing. Seven rats had missing data on one food choice because they consistently chose the other food in testing.

Therefore, the missing data for average speed for the food portion not chosen in testing was replaced with their average speed for that choice on the last three days of training. We chose the last three days of training for this calculation, because rats were consistent in their food choices by that time.

Running speed was then collapsed across all trials in testing for each rat from 1) start box to the goal arm and 2) from the beginning to the end of the goal arm. A separate between-within repeated measures ANOVA was then conducted with food choice (30 vs. 1) and days as within-subjects factors and counterbalancing (left arm/30 pellets vs. right arm/30 pellets) as a between-subjects factor.

Results

Training.

Preference. There were no significant differences in food choice during all free trials in training as shown in Figure 2. An ANOVA showed that average food choice did not significantly differ as a function of number of pellets, F (1, 37) = .23, p = .64.

Similarly, preference for the multiple and single-pellet food choice did not vary over days as shown in Figure 3. An ANOVA found no significant interaction between food choice and days, $F < 1$.

Testing.

Preference. Rats preferred the multiple pellets over the single pellet of food in testing as shown in Figure 4. An ANOVA showed a main effect of food choice, F (1, 37) = 5.34, $p < .05$, partial $\eta 2$ = .13.

Preference for the multiple and single pellet of food did not vary over days in testing as shown in Figure 5. An ANOVA showed that there was no significant interaction between food choice and days, $F < 1$.

Running speed.

Start box to end of goal arm. Rats ran significantly faster for multiple-pellets than the single pellet of food as shown in Figure 6. An ANOVA showed a significant main effect of food choice, F (1, 37) = 5.89, $p < .05$, partial $\eta 2 = .14$.

Beginning to end of goal arm. There were no significant differences in running speed between the multiple and single pellet of food as shown in Figure 6. An ANOVA showed no significant main effect of food choice, F (1, 37) = 2.31, $p = .14$.

Discussion

The results replicated those of E.J. Capaldi and colleagues (1989) showing that rats preferred the multiple pellets of food over the single, 300 mg food pellet, even though the total amount of food in both portions were equal. Moreover, consistent with other studies (Amsel et al, 1968; Traupmann, 1971) we found that rats ran significantly faster for the multiple-pellet than single-pellet food portion showing that the multiple pieces of food are more rewarding than a single, large pellet of food.

Experiment 2

One visual feature that distinguished a multiple-piece portion of food from a single, large pellet is the surface area occupied by the two portions. E. J. Capaldi and colleagues (1989) suggested that surface area may be an important factor that determines preference for a multiple-pellet over a single pellet of food. However, E.J. Capaldi and colleagues (1989) did not test this interpretation. A multiple-piece portion of food may *perceptually* look like more because the pieces occupy a greater surface area than a single, large piece of food. If surface area is critical in determining preference and motivation for a food reward, then a scattered multiple-pellet portion of food may be preferred and considered more rewarding than the same number of food pieces clustered together.

The purpose of Experiment 2 was to determine the effects of surface area occupied by multiple pieces of food (30, 10 mg pellets) on both preference and running speed in rats. We hypothesized that if surface area occupied by a portion of food is critical in determining the rewarding effects of a food, then rats will prefer and also run faster for a T-maze arm containing scattered food pieces than one containing the same number of pieces clustered together.

Method

Subjects. Twenty-four, experimentally-naïve, male, Sprague-Dawley rats from Harlan Co., Indianapolis, IN were used for the study. A power analysis showed that for a medium effect size of .18 (Cohen's d), power of .80 and .05 alpha level to detect statistical significance, only 18 rats are required. The effect size used for the power analysis was determined based on the effect size obtained in Experiment 1. Two rats failed to complete most of the training trials and were therefore excluded from data analyses. Therefore, the remaining 22 rats were used for data analyses.

Procedure. The apparatus, procedures, and data analyses were identical to Experiment 1, except here, half the rats received a scattered portion of 30, 10 mg pellets in the right arm, and the same food portion clustered together in the left arm, and the other half received the reverse.

Data analyses. Date analyses were identical to Experiment 1. Here, 12 rats had missing data on one food choice because they consistently chose the other food in testing. Therefore, the missing data for average speed for the food portion not chosen in testing was replaced with their average speed for that choice on the last three days of training. We chose the last three days of training for this calculation, because rats were more consistent in their food choices by that time.

Results

Training.

Preference. There were no significant differences in food choice in all free trials during training as shown in Figure 7. An ANOVA showed that mean food choice did not vary as a function of the surface area occupied by the food pieces in training, F (1, 20) = 2.5, p = .39.

Preference for the scattered and clustered food portions did not vary over days in training as shown in Figure 8. An ANOVA showed a non-significant interaction between food choice and days, $F < 1$. However, only on the last day of training, rats showed a marginally significant preference for the clustered (M = 1.3 ± .17) over the scattered food portion (M = .7 ± .17). An ANOVA showed a marginally significant main effect of food choice, F (1, 20) = 3.60, p = .07.

Testing.

Preference. Although rats preferred the clustered (M = 7.8 ± 1.1) over the scattered food pellets (M = 4.2 ± 1.1) in all three days of testing, an ANOVA showed no significant main effect of food choice, F (1, 20) = 2.89, p = .11.

Preference for the clustered or scattered food choice also did not vary over days as shown in Figure 9. There was a non-significant interaction between food choice and days, $F < 1$.

Since preference for the scattered and clustered food portions can extinguish with repeated testing, we examined differences in food choice as a function of the surface area occupied by the food pellets only on Day 1 of testing. Rats preferred the clustered over the scattered food portion as shown in Figure 10. An ANOVA showed that mean food choice during Day 1 of testing was significantly different as a function of the surface area occupied by the food pellets, F (1, 20) = 4.41, $p < .05$, partial η2 = .18.

Running speed.

Start box to end of goal arm. There were no significant differences in running speed between the scattered (M = 46.6 ± 3.6) and clustered (M = 49.6 ± 3.6) food portions. An ANOVA showed that running speed did not vary as a function of the surface area occupied by the food pellets, $F < 1$. We also measured running speed for the scattered and clustered food choice on Day 1 of testing only, since preference for the clustered over the scattered portion was seen only on the first day of testing. An ANOVA showed no significant differences in running speed between the scattered (M = 45.8 ± 3.1) and clustered (M = 50.1 ± 3.5) food portions on Day 1 of testing, $F < 1$.

Beginning to end of goal arm. Rats ran significantly faster for the clustered (M = 58.3 ± 2.1) than scattered (M = 51.5 ± 2.5) food portions. An ANOVA showed that running speed varied significantly between the scattered and clustered food portion in all three days of testing, F (1, 20) = 4.44, $p < .05$, partial η2 = .18. However, on Day 1 of testing only, there were no significant differences in running speed between the scattered (M = 49.5 ± 3) and clustered (M = 53.5 ± 2.8) portions, $F < 1$.

Discussion

Contrary to our hypothesis, rats preferred and ran significantly faster for the clustered than scattered food pieces, i.e., food pieces occupying a smaller surface area were preferred over a similar number of pieces scattered over a larger area. However, while preference for clustered over scattered food pellets developed gradually by the last day of training and first day of testing, preference for the clustered pellets decreased rapidly with repeated testing. In addition, preference for the scattered and clustered food pellets on the first day of testing did not translate to running speed, showing that the rewarding effects of surface area occupied by food pieces are small and transitory.

General Discussion

Experiment 1 showed that multiple pieces of food are more rewarding than a single piece and Experiment 2 showed that multiple pieces occupying a smaller area were preferred over one occupying a larger area. Together, these studies show that the rewarding effects of number of food pieces in animals is not mediated by the larger surface area occupied by the multiple pieces than the single piece of food.

Preference and faster running speeds for multiple pellets than a single pellet of food are consistent with findings from other animal studies that showed that rats ran significantly faster for multiple (4-22) pellets of food than a single, equicaloric food pellet (Amsel et al., 1969; Daly, 1972; Traupmann, 1972) and that rats preferred multiple (four, 75 mg) pellets over a single (300 mg) pellet (E.J. Capaldi et al., 1989). Although the pellets in the thirty-pellet condition were smaller than the single large pellet in

Experiment 1, it is unlikely that rats prefer the multiple pieces of food due to their smaller size because both rats and nonhuman primates have been shown to prefer large pieces of food over smaller ones (Menzel, 1961; Menzel & Davenport, 1962; Yoshioka, 1930). One interpretation for these findings is that perhaps animals, like humans, may be vulnerable to conservation effects. Piaget (1952) believed that children are unable to understand that an object's physical properties remain the same even if their arrangement or appearance is changed. Therefore, similar to humans, animals may be vulnerable to conservation effects and are unable to conserve the weight of the two food portions when the food is presented in many pieces than as one piece. This makes evolutionary sense because it would be beneficial for animals to optimally forage for the maximal amount of food in a given area (Honig & Stewart, 1989).

In Experiment 1, we also found that there was no significant preference for the multiple over the single pellet in training and that preference in training did not vary over days. However, in testing rats significantly preferred the multiple pieces of food over the single piece. This is not surprising given that preference for multiple pellets of food over the single pellet was not significant until the 30th trial in E.J. Capaldi et al (1989) which is equivalent to the first day of testing in our experiment. Moreover, similar to E.J. Capaldi et al (1989) preference for the multiple over the single pellet of food did not diminish with repeated testing (23 days), showing that preference for multiple pellets of food do not habituate with continued testing.

In Experiment 1, rats also ran significantly faster for a multiple than single pellet of food in testing only from the start box to the end of the goal arm, and not in the goal arm itself. This is consistent with Campbell et al (1972) who found that running speed for 22, 45 mg pellets was significantly greater than the single, 1000 mg pellet only in the run section and not the goal sections of a runway. Perhaps, on the entering the goal arm, the sight of the food itself (whether multiple or single) is rewarding, resulting in non-significant differences in running speed between the multiple and single pellet of food in the goal arm.

Another notion for preference of multiple pellets over the single pellet may be that multiple pieces take up a larger surface area and may therefore be perceived to contain more food than a single pellet. This was tested in Experiment 2. However, contrary to our expectations, in Experiment 2, rats preferred the clustered over the scattered food pellets. One interpretation for these findings may be provided by the optimal foraging theory. The optimal foraging theory states that animals will use strategies that will maximize food intake (calories per unit of time) and minimize predation risk (Kamil & Roitblat, 1985). Consistent with this idea, animals will eat faster in lighted, exposed, and novel environments where the risk of predation is higher than if eating in dark, covered, and familiar environments (Whishaw, Dringenberg, & Comery, 1992). Since scattered food pieces may take longer to eat and may consequently increase predation risk or the loss of food to conspecifics, it would be beneficial for the rat to prefer a food patch where the food pieces are already clustered together than when scattered. However, preference for the clustered food pellets did not translate to running speed and decreased rapidly with repeated testing.

To conclude, rats prefer multiple pellets of food over an equicaloric, single pellet of the same food and that this preference is not mediated by the larger surface area occupied by the pellets. Second, rats prefer pellets clustered together than when scattered, possibly due to reduction in the time and effort required in consuming a food portion where the pellets are clustered together. Future studies should consider the interaction of type of food with number, size, and surface area occupied by food pieces on preference and motivation for a food reward in rats.

CHAPTER 3

SERVING FOOD IN PIECES REDUCES FOOD INTAKE

Several visual characteristics of a food can affect the amount of food consumed. For example, increasing the portion sizes of foods can increase energy intake in both children and adults (Dilberti, Bordi, Conklin, Roe, & B.J. Rolls, 2004; Fisher & Kral, 2008; Levitsky & Youn, 2004; B.J. Rolls et al., 2002; B.J. Rolls et al., 2004). In addition, varying the size of food pieces affects the amount of food consumed; people eat more when given larger pieces (Marchiori et al., 2011; Marchiori et al., 2012). Marchiori and colleagues (2011) found that adults ate more when given 10 large candies than those cut into 20 bite-sized pieces. In a subsequent study, Marchiori et al (2012) found that children ate more when given 18 large cookies than 36 bite-sized ones. In addition, Weijzen et al (2008) found that subjects ate more when given six large candy bars than those given the same amount of candy presented in 66 bite-sized pieces.

Along with size, however, another *visible* characteristic of food that varied in the aforementioned studies is the *number* of food pieces i.e. 10 large candies were cut into 20 small pieces (Marchiori et al., 2011) and 18 large cookies were cut into 36 small pieces (Marchiori et al., 2012). Therefore, the purpose of the present studies were to determine the effects of number of pieces, independent of size, on energy intake from that portion as well as from a test meal given later.

Studies investigating number of pieces in animals have shown that multiple pieces of food are preferred and are also more rewarding than the same amount of food presented in a single piece. Rats ran faster for multiple pellets of food than an equicaloric, single pellet of food, showing that multiple pieces of food are more rewarding to animals than a single piece (Campbell et al., 1972; Traupmann, 1971). E. J. Capaldi and colleagues (1989) found that rats also preferred a T-maze arm containing multiple (four, 75 mg) pellets to one containing a single (300 mg) pellet (E.J. Capaldi et al., 1989). Here, we investigated the effects of number of food pieces on preference and amount of food consumed in college students, with the total amount of food held constant. We hypothesized that subjects given food in pieces will prefer and also eat less of that food as well as from a subsequent test meal than those choosing the one-piece chicken serving.

Experiment 1

Method

Subjects. Two hundred and thirty-nine undergraduate students (132 males, 107 females) from an introductory psychology class at Arizona State University participated in the study. A total of 23 subjects were eliminated (two because they were taking appetite suppressant medications, 15 because of existing colds, respiratory disorders and other medical conditions, one due to dietary restrictions, and five others because they did not skip breakfast prior to the experiment). Subjects excluded from data analyses were not significantly different from those included in height, weight, or body mass index (BMI). Therefore, 215 subjects (121 males, 94 females) were included for data analyses and had a mean weight of 152.3 lb, mean height of 67.8 in, and mean BMI of 23.3. The study was approved by the Human Subjects Institutional Review Board.

Foods. A 24 g (50 kcal) portion of Tyson's fully-cooked chicken breast was given either whole or segmented into four equal-sized pieces. The frozen chicken filet breasts were heated in the oven at 425°F for 15 min before serving. Table 1 shows the weights, calories, and macronutrient content of the chicken portion served.

Design. A one-factor between-subjects design was used to examine the effects of number of pieces on 1) preference and 2) energy intake. Preference was measured by giving subjects the choice between the four-piece chicken portion (multiple-piece portion) and the same portion of chicken left whole (single-piece portion). Energy intake was then measured from the chosen four-piece and single-piece chicken serving as well as from a test meal given 20 min after the chosen chicken serving. We used a 20 min delay between the chicken portion and the test meal because it takes at least 20 min to develop satiety following a meal (Spiegel, Shrager, & Stellar, 1989; Stellar & Shrager, 1985).

Procedure. On arrival, at 11 am, subjects were seated in individual cubicles and instructed to report gender, weight, height, age, if they were taking any appetite suppressant medications, and if they had eaten any food or drink in the last 12 hours. After completion of the questionnaires, subjects received both the four-piece (multiple-piece serving) and single, uncut chicken (single-piece serving) and were asked to choose one sample of food they wanted to eat and rate. Preference for the multiple-piece and single-piece chicken serving was then recorded by the experimenter. Subjects were then instructed to eat as much as they wanted from the chosen chicken serving and then rate the palatability of the chicken using a rating scale adapted from Bartoshuk (2000). The scale ranged from -100 = “Strongest Imaginable Disliking” to +100 = “Strongest Imaginable Liking” for pleasantness and from 0 = “None” to 100 = “Extremely” for saltiness, sweetness, bitterness, and sourness. Once subjects ate the chicken portion, any leftover chicken was then weighed and amount of food consumed was recorded. Energy intake was then calculated based on information obtained from the food manufacturer.

Following the chicken serving, subjects were asked to complete some "filler" questionnaires. The first questionnaire they completed was the eating inventory questionnaire (Stunkard & Messick, 1985) and the second was a food frequency questionnaire identical to the one used in E. D. Capaldi, Owens, and Privitera (2006). These filler questionnaires were used to pass some time before presenting the test meal and to discourage subjects from talking to each other about the experiment. After the filler questionnaires, subjects were told that they would receive a "complimentary lunch" (test meal) in appreciation for their participation similar to the deception used in E.D. Capaldi et al (2006). Table 1 shows the weights, calories and macronutrient content of the foods served during the test meal. Each subject was given all six plates of foods and instructed to eat as much or as little as they wanted from the test meal. Subjects could also ask for seconds of any food. The amount consumed (g) from leftover foods in the test meal was then recorded and energy intake (kcal) was calculated from information available from the food manufacturer. Finally, subjects were given debriefing forms and then dismissed.

Data analyses. The binomial test was used to determine if the number of subjects showing a preference for the multiple or single-piece chicken serving was significant. Separate one-factor between-subjects ANOVAs were used to determine the effects of the number of food pieces on energy intake (kcal) from the chicken portion and test meal.

Results

Preference for the four-piece and one piece chicken portion did not vary by gender. In addition, energy intake from the chicken portion and test meal did not vary by gender. Therefore, the data were pooled for successive analyses.

Preference. Out of the 215 subjects, 148 subjects chose the four-piece and 67 subjects chose the once-piece chicken portion. A binomial test of this distribution was significant ($p < .001$).

Energy intake.

Chicken. Since the majority of subjects chose the multiple-piece over the single-piece chicken portion, the homogeneity of variance assumption was violated. Therefore, a Welch test was conducted to determine the effects of number of chicken pieces chosen on energy intake from the chicken serving. Subjects ate fewer calories from the four-piece than single-piece chicken portion as shown in Figure 11 (see inset graph). A Welch test showed a significant main effect of number of pieces on energy intake, *Welch's F* (1,199.6) = 10.28, $p < .001$, adjusted $\omega^2 = .04$

Test meal. Subjects ate fewer calories from the test meal following the four-piece than one-piece chicken portion as shown in Figure 11. An ANOVA showed a marginally significant difference in test meal intake as a function of number of pieces, F (1, 213) = 3.84, $p = .05$, $\eta 2 = .02$.

Other ratings.

Pleasantness ratings of the chicken serving. Mean pleasantness ratings of the four piece (M = 52.4 ±2.23) and one-piece chicken serving (M = 54.8 ±3.54) did not differ, $F < 1$, indicating that overall the chicken portion was similar in palatability.

Discussion

The results showed that 69% of the subjects preferred the four-piece portion of chicken. Additionally, subjects ate less of the four-piece than single-piece chicken serving, showing that a multiple-piece portion was more satiating than a single-piece portion. Presenting the multiple-piece serving also reduced further food intake. Subjects who ate the multiple-piece serving ate less of a common test meal than those who ate the single-piece serving, however, this difference narrowly missed significance. Lower energy intake following the multiple- than single-piece chicken portion was not due to palatability of the meal as indicated by non-significant differences in palatability ratings.

Possibly, energy intake from the multiple-piece portion was lower because it may have been eaten more slowly than the single-piece portion, resulting in reduced energy intake. Weijzen et al (2008) found that 66 bite-sized pieces of chocolate were eaten slower and in smaller amounts than six large chocolate bars. Eating slowly allows sufficient time for the release of satiation signals, resulting in a decreased desire to eat, and lower energy intake (Azrin et al., 2008; Kissileff et al., 2008; Martin et al., 2007). To evaluate this notion, in Experiment 2 we measured time spent eating and rate of eating a multiple- and single-piece portion to determine if time spent eating and speed of eating that food varied based on the number of pieces. Second, although test meal intake was lower after the multiple- than single-piece chicken serving, the difference in intake was not large probably because of the small portion of chicken served in Experiment 1. So, we increased the size of the portion given first as well as the amount of available food in the test meal in Experiment 2 in hopes of observing larger differences in test meal intake following the multiple- and single-piece portion. Third, about 70% of the sample chose the four-piece over the single-piece chicken serving resulting in unequal ns. Therefore, we randomly assigned subjects to receive the multiple-piece or single-piece conditions to ensure equal number of subjects in both groups. Lastly, we used a bagel instead of the chicken serving, to determine if the effects of number of pieces of food on energy intake are also generalizable to carbohydrate foods.

In Experiment 2, we randomly assigned subjects to receive a single uncut, bagel (single-piece) or one cut into four pieces (multiple-piece) and measured amount (g) and energy consumed (kcal) from the bagel and subsequent test meal. We hypothesized that subjects given the four-piece bagel will eat less of the bagel and subsequent test meal than those given the single, uncut bagel.

Experiment 2

Method

Subjects. Three hundred and thirteen college students (156 males, 156 females) from an introductory psychology class at Arizona State University participated in the study. One subject did not provide information on gender. One was removed due to dietary restrictions, and five others were removed from the study because they did not skip breakfast prior to the experiment. Subjects included in data analyses were free of colds, respiratory disorders, food allergies, medical conditions, food restrictions, and were not following any dietary programs. Subjects excluded from data analyses were not significantly different in weight, height, or BMI. Therefore, a total of 301 subjects (146 males, 154 females) were included for data analyses with a mean height of 67 in, mean weight of 148 lb, and mean BMI of 22.4. The study was approved by the Arizona State University Human Subjects Institutional Review Board.

Procedure. All procedures and data analyses were identical to Experiment 1, except that subjects were randomly assigned to receive a quartered bagel (multiple-piece) or an uncut bagel (single-piece) which was smeared with cream cheese. There were no significant differences in weight, height, or BMI between subjects in the two conditions. Time spent eating the bagel was recorded using a stopwatch by the experimenters and eating rate calculated. Eating rate of the bagel (g/sec) was calculated by dividing the total amount of bagel consumed (g) by the total time spent eating the bagel (sec). Table 2 shows the weights, calories, and macronutrient content of foods used in this study.

Results

Energy intake.

Bagel. As Figure 12 shows (see inset graph), subjects ate fewer calories when given the four-piece than single, uncut bagel, F (1,299) = 4.30, $p < .05$.

Test meal. As Figure 12 shows, subjects ate fewer calories from the test meal following the four-piece than single, uncut bagel, F (1, 299) = 5.97, $p < .05$.

Other ratings.

Eating duration and eating rate. Eating duration and eating rate of the four-piece and one-piece bagel are shown in Table 3. Although subjects ate fewer calories when given the four-piece than single-piece bagel, the rate of eating (g/sec) and the time spent eating (sec) the four-piece and one-piece bagel did not vary, $Fs < 1$.

Pleasantness ratings of the bagel. Mean pleasantness ratings of the four-piece and single, uncut bagel are shown in Table 3. Pleasantness of the four-piece and one-piece bagel did not vary based on number of pieces ($F < 1$) indicating that overall, the bagel was similar in palatability.

Discussion

The results showed that subjects ate less when given the multiple-piece bagel than those given the single, uncut bagel. The satiating effects of the multiple-piece portion also extended to a common test meal given later. Subjects given the four-piece bagel ate fewer calories from the test meal than those given the single-piece bagel. Together, these results show that increasing the number of pieces in a meal can decrease energy intake from that meal and also from a subsequent meal.

Although subjects consumed fewer calories from the multiple-piece than single-piece bagel in Experiment 2, time spent eating and eating rate of the bagel did not differ as a function of the number of pieces. Therefore, time spent eating or rate of eating the bagel was not responsible for variations in energy intake as a function of number of pieces.

General Discussion

Experiments 1 and 2 showed that a multiple-piece portion of food is preferred and also eaten in smaller amounts than a single-piece portion. In addition, consumption following a multiple-piece food portion was also lower than that following a single-piece food portion. It should be noted that although we used a small portion of food as the target food (50 kcal portion in Experiment 1 and 200 kcal portion in Experiment 2), we were still able to show a significant differences in the amount of food consumed between the multiple-piece and single-piece food portion. Moreover, gender did not interact with number of pieces on energy intake from the target food portion and test meal in both experiments.

Possibly, food cut into smaller pieces resembles “snack” foods, which are typically not eaten to satiation, resulting in lower energy intake. Nisbett and Storms (1972) observed that subjects ate more when given four quartered sandwiches (16 pieces) than 32 bite-sized ones. The authors suggested that perhaps subjects perceived 32 bite-sized pieces as “snack” foods and the 16 large sandwiches as meals (Nisbett & Storms, 1972). However, if the quartered bagel used in our study was indeed considered a snack, then subjects should have consumed more from the test meal than those given the single, uncut bagel because snack foods are less satiating than meals. Consistent with this notion, E. D. Capaldi et al (2006) showed that when subjects ate a food categorized as snack they ate more from a subsequent meal than those who categorized them as meals. Therefore, it is unlikely that subjects considered the quartered bagel as “snack” and the single, uncut bagel as a “meal”.

To test the idea that the multiple-piece portion decreased energy intake due to eating duration, in Experiment 2 we measured time spent eating and eating rate as a function of number of pieces. There were no differences in eating duration or eating rate as a function of number of bagel pieces. The relationship between eating duration and energy intake is mixed in the literature. Although some studies show that eating slowly results in lower energy intake because it allows sufficient time for satiation and inhibits food intake (Azrin et al., 2008; Ferster et al., 1962; Kissileff et al., 2008; Martin et al., 2007; Melanson, 2004; Spiegel, 2000), others showed no effect or higher food intake

(Karl, Young, & Montain, 2011; Yeomans, Gray, Mitchell, & True, 1997). But since eating duration did not vary, this variable did not play a role in Experiment 2's results.

Another notion is that since the pieces in the four-piece bagel were smaller in size than the single-piece bagel, differences in bite size may have led to differences in energy intake. Taking large bites leads to gorging, which then reduces feelings of fullness, increases the desire to eat, and ultimately increases food intake (Burger et al., 2011b; de Wijk et al., 2008; Fisher & Kral, 2008; Forde, Kuijk, Thaler, de Graaf, & Martin, 2013a; Kral et al., 2001; Weijzen et al., 2009; Zjilstra et al., 2009). Consistent with this idea, Weijzen et al (2008) found that large candy pieces were eaten rapidly and in greater amounts than small candy pieces. They hypothesized that eating rate may have varied due to larger bites taken from the large food pieces. However, taking large bites results in a corresponding decrease in time spent eating and an increase in eating rate (Weijzen et al., 2008). Since eating duration and eating rate did not vary based on the number of pieces used in our study, it is unlikely that differences in bite size are responsible for variations in energy intake between the multiple- and single-piece portions.

Another reason for decreased energy intake from a multiple-piece portion may be a greater expected satiation from that food relative to the single-piece portion. Many studies show that expected satiation, and not palatability, determines the quantity of food to be consumed (Brunstrom, Shakeshaft, & Alexander, 2010; Brunstrom, Shakeshaft, & Scott-Samuel, 2008). Brunstrom and colleagues (2008, 2010), suggested that expected satiation may be a product of our learned experiences with food. Therefore, a four-piece portion may be expected to deliver greater satiation because subjects have "learned" that more pieces of something may mean something greater in quantity. Consistent with this hypothesis, consumers in a marketing study judged a snack packet with an image of 15 pretzels to contain a greater number of pretzels than a package containing an image of three pretzels, even though the actual quantity of pretzels in the package were the same (Madzharov & Block, 2010). Perhaps, subjects expected the four-piece portion in both experiments to contain more food than the single-piece portion, resulting in an increase in expected satiation and lower energy intake.

Yet another idea is that perhaps a multiple-piece portion looks like more food because it takes up a larger surface area on the plate than a single-piece portion. These errors in perceptual quantity based on the surface area occupied by a food may be explained by the Delbouef illusion (Van Ittersum & Wansink, 2011). The Delbouef illusion is an optical illusion where the perceived size of one circle changes relative to another circle, in this case, the size of the food portion relative to the size of the plate in which it is served (Nicolas, 1995). This illusion ultimately affects quantity estimations. Consistent with this idea, Fisher and Kral (2008) found that children perceived a fixed portion of macaroni and cheese as more food when spread out over a larger than smaller area on the plate, even though plate size was held constant (Fisher & Kral, 2008). Perhaps, then the quantity of a multiple-piece portion of food may be overestimated because it occupies a larger surface area on the plate than a single-piece portion and this overestimation may have ultimately decreased intake from that portion of food as well as decreased the size of the subsequent meal.

Although differences in energy intake between the multiple-piece and single-piece portions in Experiments 1 and 2 were small, this difference was comparable to

Weijzen et al (2008)'s study. Weijzen et al (2008) found a 6 g difference in intake between 66 candy pieces and 6 large candy pieces and we found a 4 g difference in intake between the four-piece and six-piece chicken serving and a 10 g difference in intake between the four-piece and one-piece bagel. Results from Experiments 1 and 2 extends findings from previous studies on size and number and shows that the satiating effects of a multiple-piece portion of food also extends to a later meal, resulting in a decrease in total caloric intake. Total intake (i.e. intake from the target food and test meal together) was markedly lower when given a multiple-piece portion than single-piece portion. In Experiment 1 subjects who chose the multiple-piece chicken serving ate 25 kcal less overall than those who chose the one-piece chicken serving. In Experiment 2, subjects given the four-piece bagel ate 76 kcal less overall than those given the one-piece bagel. Therefore, these studies show that although differences in the amount of food consumed between foods varying in pieces was small, the overall energy intake is lower when given a multiple-piece than single-piece portion of food.

To conclude, the results from these studies demonstrate that a food portion cut into discrete number of pieces may perceptually look like more food than one uncut and this perceptual bias may ultimately affect the amount of food consumed. Therefore, cutting up a whole food into small pieces may be used as one strategy for portion control.

CHAPTER 4

SCATTERED FOOD PIECES REDUCE ENERGY INTAKE MORE THAN CLUSTERED PIECES

Large food pieces can increase energy intake more than smaller ones. Nisbett and Storms (1972), found that subjects ate more when given four, quartered sandwiches (16 pieces) than the same amount of sandwiches cut into 32 bite-sized pieces. Marchiori and colleagues (2011, 2012) also found that adults ate more when served 10 large candy pieces than those cut into 20 bite-sized pieces and children ate more when served 18 large cookies than those cut into 36 bite-sized pieces.

Large food pieces can influence food intake by food quantity perceptions. Scisco and colleagues (2012) found that subjects perceived a 16-piece Jell-O portion to contain more food than the same amount of Jell-O presented in nine pieces. The authors hypothesized that perhaps, a food cut into more pieces is perceived to contain more food because it takes up a larger surface area than one cut into fewer pieces. When a portion of food is served on a plate, people tend to focus on the ratio of the amount of food to the plate to determine the quantity of food. Fisher and Kral (2008) found that children perceived a macaroni and cheese portion spread out over a larger area on a plate as more food than the same amount spread on a smaller area on the plate, even though plate sizes were identical (Fisher & Kral, 2008).

One explanation for incorrect estimations of food based on the spread of the food portion may be explained by the Delbouef illusion. The Delbouef illusion is a visual illusion where the size of one circle is perceived to change relative to another circle, in this case, the size of the food portion relative to the size of the plate in which it is served

(Nicolas, 1995) resulting in perceptual errors in quantity estimations. As a result of this illusion, foods served on larger plates or bowls may be displaced towards the center of the plate, resulting in a significant underestimation of food (called contrast effects) and foods served on smaller plates or bowls displace away from the center, resulting in a significant overestimation of food (called assimilation) (Van Ittersum & Wansink, 2011). These assimilation and contrast effects ultimately affect the amount of food served. Van Ittersum and Wansink (2011) found that subjects poured less soup and cereals into a smaller than larger bowl due to overestimation of the diameter of the smaller bowl.

Studies investigating contrast and assimilation effects however, have mostly focused on amorphous foods , i.e., foods that take up the shape of the container such as macaroni and cheese (Fisher & Kral, 2008), cereals (Van Ittersum & Wansink, 2011) soup (Van Ittersum & Wansink, 2011), and ice-cream (Wansink et al., 2006b).

Here, we extend assimilation and contrast effects obtained from amorphous foods to foods with a discrete number and size. We kept the size and number of pieces of food constant and manipulated the surface area occupied by a food portion by scattering or clustering five, equal-sized pieces of a chicken serving on a plate. We measured the amount of food consumed from the chicken serving and from a common test meal given 20 min later. If food pieces occupying a larger surface area are perceived to contain more food (due to contrast effects), then energy intake will be lower when given a scattered than clustered five-piece chicken serving and energy intake following the scattered chicken serving will also be lower than that following the clustered chicken serving.

Method

Subjects

A sample of 98 undergraduate students (46 males, 52 females) from an introductory psychology class at Arizona State University participated in the study. A power analysis showed that for a large effect size (.40), power of .80, and alpha level of .05 to detect statistical significance, a sample of 84 subjects are needed. The effect size used for the power analysis was established based on results obtained from similar studies on size and number of food pieces on food intake (Marchiori et al., 2011; Marchiori et al., 2012; Weijzen et al., 2008). Four subjects were excluded due to dietary restrictions and one subject was excluded due to participation in dietary and physical programs. Subjects included for analyses were free of medical conditions, food allergies, and dietary restrictions, colds, respiratory disorders, and not taking any appetite suppressant medications. A final sample of 93 subjects (41 males, 52 females) with a mean weight of 149 lb, mean height of 68.2 in, and mean BMI of 22.4 participated in the study. The study was approved by the Arizona State University Human Subjects IRB and experiment procedures were performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Foods

A 65 g (85 kcal) portion of Tyson's fully-cooked chicken breast was segmented into five equal-sized pieces (3.0 cm X 3.0 cm X 1.0 cm). When scattered, the surface area occupied by the chicken pieces was 260 cm^2 and when clustered, the area occupied was 71 cm^2. In the scattered portion, the space between the pieces was not constant, because the pieces were placed in a random order. In the clustered portion, the food pieces were clustered together in the center of the plate. The frozen chicken filet breasts were heated in the oven at 425 °F for 15 min before serving. Subjects were randomly assigned to Groups Clustered (n = 48) and Scattered (n = 45). There were no significant differences in height, weight, or BMI of subjects between subjects in the two conditions.

Design

A one-factor between-subjects design was used to examine the effects of surface area occupied by pieces (Scattered vs. Clustered) on energy intake. Energy intake was measured from the chicken serving as well as from a test meal given 20 min after the chicken serving. We used a 20 min delay between the chicken portion and the test meal because it takes at least 20 min to develop satiety following a meal (Spiegel et al., 1989; Stellar & Shrager, 1985).

Procedure

On arrival, at 11 am, subjects were seated in individual cubicles and instructed to report gender, weight, height, age, if they were taking any appetite suppressant medications, and if they had eaten any food or drink in the last 12 hours. After completion of the questionnaires, subjects received either the scattered or the clustered chicken portion and were instructed to eat as much as they wanted from the chicken serving and then rate the palatability of the chicken serving using a rating scale adapted from Bartoshuk (2000). The scale ranged from -100 = “Strongest Imaginable Disliking” to +100 = “Strongest Imaginable Liking” for pleasantness and from 0 = “None” to 100 = “Extremely” for saltiness, sweetness, bitterness, and sourness. Once subjects ate the chicken portion, any leftover chicken was then weighed and amount of food consumed was recorded. Energy intake was then calculated based on information obtained from the food manufacturer.

Following the chicken serving, subjects were asked to complete some "filler" questionnaires to ensure a 20 min delay between the chicken serving and subsequent test meal. The first questionnaire they completed was the eating inventory questionnaire (Stunkard & Messick, 1985) and the second was a food frequency questionnaire identical to the one used in E. D. Capaldi et al (2006). These filler questionnaires were used to introduce a delay between the first portion and the test meal and to discourage subjects from talking to each other about the experiment. After the filler questionnaires, subjects were told that they would receive a "complimentary lunch" (test meal) in appreciation for their participation. The weights, calories, and macronutrient content of the foods served in this study are provided in Table 4. Each subject was given all six plates of foods and instructed to eat as much or as little as they wanted from the test meal. Subjects could also ask for seconds of any food. The amount consumed (g) from leftover foods in the test meal was then recorded and energy intake (kcal) was calculated from information available from the food manufacturer. Finally, subjects were given debriefing forms and then dismissed.

Data Analyses

Separate one-factor between-subjects ANOVAs were used to determine the effects of number of food pieces on mean energy intake (kcal) from the chicken serving, energy intake from the test meal, eating duration (sec), eating rate (g/sec), and pleasantness ratings of the chicken serving. Eating rate (g/sec) was calculated by dividing the total amount of chicken consumed (g) by the total time spent eating the chicken serving (sec).

Results

Gender did not interact with surface area occupied by chicken serving on energy intake from the chicken serving and test meal. Therefore, the data were pooled for successive analyses.

Energy Intake

Chicken serving. Group Scattered ate significantly fewer calories from the chicken serving than Group Clustered as shown in Figure 13 (See inset graph). Energy intake from the chicken serving varied significantly by group, F (1, 91) = 6.22, $p < .05$, $\eta 2 = .06$.

Test meal. Group Scattered ate significantly fewer calories from the test meal than Group Clustered as shown in Figure 13. Test meal energy intake varied significantly by Group, F (1, 91) = 4.62, $p < .05$, $\eta 2 = .05$.

Other Ratings

Eating duration and eating rate. Table 5 shows eating duration and eating rate, as a function of surface area occupied by the pieces. Although Group Scattered ate the chicken serving in smaller amounts than Group Clustered, the rate of eating (g/sec) and the time spent eating the chicken serving (sec) did not differ based on surface area occupied by the pieces, $Fs < 1$.

Pleasantness ratings of the chicken serving. Table 5 shows mean pleasantness ratings of the chicken serving as a function of the surface area occupied by the pieces. Mean pleasantness ratings of the chicken serving did not differ based on the surface area occupied by the chicken pieces, $F < 1$, showing that the chicken serving was similar in palatability.

Discussion

Consistent with our hypothesis, energy intake was lower when given the scattered than clustered pieces, even though there were no differences in time spent eating, eating rate, or palatability between the two portions. In addition, test meal intake was lower following the scattered than the clustered food portion showing that the surface area occupied by a portion of food may be important in determining the quantity of food consumed from a subsequent meal. Therefore, these results demonstrate that scattering food pieces over a larger area may be perceived to contain more food than one occupying a smaller area, resulting in lower intake from that food as well as from a test meal given later.

Since there were no differences in the microstructure of eating, perceptual errors in quantity estimation based on the spread of the food portion on the plate may be responsible for variations in energy intake. The scattered food portion may be overestimated relative to the clustered food portion (due to contrast effects), resulting in lower energy intake. Therefore, similar to the results obtained with amorphous foods (Fisher & Kral, 2008; Van Ittersum & Wansink, 2011), we found that even a food cut into distinct number of pieces may influence errors in quantity estimations and ultimately affect the amount of food consumed.

It important to note that total intake was markedly lower when given a scattered than clustered portion. Subjects given the scattered portion ate 89 g (98 kcal) less overall than those given the clustered chicken portion, showing that overall food intake is much lower when given a portion of food occupying a larger surface area on the plate than one occupying a smaller area. Therefore, future studies should focus on surface area occupied by food as an important dimension of food affecting food intake.

CHAPTER 5

A REVIEW OF VISUAL CUES ASSOCIATED WITH FOOD AND THEIR EFFECTS ON FOOD ACCEPTANCE AND CONSUMPTION

We live in a world where we are constantly bombarded with food and food images either through media or through the proliferation of eating locations that advertise and sell large portions of palatable, energy-dense foods. So it is not surprising that efforts to reduce the incidence of obesity have been largely unfruitful. According to the World Health Organization, about 1.4 billion people were overweight and nearly 500 million people were obese in 2008. In the United States alone, about 35% of adults and 17% of children were obese from 2009 to 2010 (Ogden, Carroll, Kit, & Flegal, 2012). If the current trends in obesity continue, it is expected that almost half the American population will become obese by 2030 (Finkelstein et al., 2012). The simplest cause of obesity is an increase in energy intake or a decrease in physical activity. Since physical activity has not changed much in the past two decades (Finkelstein et al., 2005), most of the research is now focused on energy intake as a plausible target for obesity prevention and treatment. Several internal and external food cues act independently, additively, or interactively to affect food intake. The focus of this review article, however, is on external cues directly associated with the food and its effects on food intake.

Although many people cite taste as the most important factor affecting their food intake (Glanz et al., 1998) in many cases the first sensory contact with food is through the eyes. In fact, the mere sight of food can facilitate the subjective desire to eat the target food (Cornell, Rodin, & Weingarten, 1988; Hill, Magson, & Blundell, 1984; Marcelino, Adam, Couronne, Koster, & Siefferman, 2001) and activate brain areas and neural pathways associated with reward (Beaver, Lawrence, Ditzhuijen-Davis, Woods, & Calder, 2006; La Bar et al., 2001; Morris & Dolan, 2001; Stoeckel, Cox, Cook III, & Weller, 2007). In addition, before a food is consumed, the appearance of the meal provides expectations about the taste quality, flavor, and palatability of food which may ultimately affect food acceptance and consumption (Hurling & Shepherd, 2003).

The purpose of this review then is to identify the various visual cues associated with food intake and to address some interpretations for these different cues. There have been previous reviews of neural responses to food and food images (van der Laan, Ridder, Viergever, & Smeets, 2011) and the effects of sight of food on internal, physiological processes (Mattes, 1997). However, there is no previous review of the effects of visual cues on eating behaviors. Here, we review the research involving the effects of the sight of food on eating behaviors, and specifically, the amount of food consumed.

Why Are Visual Cues From Food Important?

Visual exposure to a novel food before consumption is shown to be particularly effective in introducing new foods to children. Neophobia or the "fear of something new" is an adaptive trait that typically peaks between two to five years of age and can decrease the consumption of fruits, vegetables, and meats (Cooke, Carnell, & Wardle, 2006; Cooke, Wardle, & Gibson, 2003; Pliner, 1994). Visual exposure to a novel food can reduce neophobia and facilitate acceptance. When children were exposed to pictures of novel food pictures or actual foods before trying them, children showed a greater willingness to try those foods than those not visually exposed (Birch, McPhee, Shoba, Pirok, & Steinberg, 1987; Houston-Price, Butler, & Shiba, 2009). Similarly, children presented with a visually similar, familiar fruit before a novel fruit showed a greater willingness to try the novel fruit than those exposed only to the novel fruit (Dovey et al., 2012).

Second, not only can visual exposure increase willingness to try a novel food, but enhancing the visual appeal of a novel food can also encourage consumption. Jansen, Mulkens, and Jansen (2010) enhanced the visual appeal of a novel fruit by presenting it in an attractive fashion (i.e. pieces of fruit were pierced with a toothpick and displayed on a watermelon slice). They found that children ate more of the visually appealing fruits than a simple mix of fruits served on a white plate (Jansen et al., 2010). In addition, Zampollo and colleagues (2012) found that children preferred to have more food items, empty space, and variety of foods and colors on their plates than adults, showing that a varied, attractive meal are important determinants of preference in children (Zampollo, Kriffin, Wansink, & Shimizu, 2012).

Third, arranging foods on a plate can affect our expectations and ultimately, liking of the food. For example, strawberry-flavored mousse placed on a white plate was judged to be more flavorful, sweeter, and palatable than the same food presented on a black plate (Piqueras-Fiszman, Alcaide, Roura, & Spence, 2012). The authors hypothesized that the color-contrast produced with the food on the white plate may have enhanced expectations about the taste of food, increased perceived flavor intensity, and facilitated acceptance (Piqueras-Fiszman et al., 2012). Similarly, arranging the foods on a plate in an orderly way can enhance intake. When meal ingredients were presented in a neat and orderly fashion, subjects liked the taste of the meal more than when meal ingredients were presented in a random, messy way (Zellner et al., 2011). Even "balancing" i.e. perceived heaviness of the ingredients on a plate can affect intensity ratings and liking of a food. A multi-colored "balanced" food plate was rated higher in attractiveness than a single-colored, balanced plate (Zellner, Lankford, Ambrose, & Locher, 2010).

Fourth, visual exposure to food elicits the physiological release of saliva and other regulatory peptides required for digestion. For example, the mere sight of food (and food pictures) and smell stimulates the physiological release of saliva (Christenzen & Navazesh, 1984; Klajner, Herman, Polivy, & Chhabra, 1981; Wooley & Wooley, 1973). The release of saliva is the first step in the digestive process as it contains key enzymes required for the breakdown of nutrients before complete digestion in the stomach (Pedersen, Bardow, Jensen, & Nauntofte, 2002). Blood insulin levels also peak when exposed to the sight and smell of food in response to an anticipatory increase in blood glucose following food consumption (Johnson & Wildman, 1983; Sjostrom, Garrelick, Krotkiewski, & Luyckx, 1980; Woods, 1991). Woods (1991) argued that this anticipatory increase in insulin levels (called the cephalic phase insulin response) may be an adaptive response to protect the organism from drastic changes in glucose levels and to maintain homeostasis. In addition, the sight of food can increase subjective sensations of hunger and appetite which are partially responsible for initiating food intake (Bossert-Zaudig, Laessle, Meiller, Ellgring, & Pirke, 1991).

Fifth, varying the appearance of a portion of food can affect perceptions of variety in a meal, and ultimately affect energy intake. Seeking a variety of foods may be an adaptive trait to protect the organism from nutritional deficiencies (E.T. Rolls, 1981). Levistky et al (2012) for example, varied the presentation of a vegetable-stir fry and pasta meal by presenting the ingredients of these meals either separately or mixed together. The results showed that when the ingredients were presented separately, subjects ate more than when the ingredients were mixed together. The authors suggested that segregating food into discrete units increases energy intake by increasing the perceived variety of foods available for consumption (Levitsky et al., 2012).

Lastly, the food portion served on a plate may serve as a visual benchmark or guide to determine the appropriate amount of food to consume. These visual benchmarks or guides are referred to as “consumption norms” that can dictate the amount of food consumed in a meal (Wansink & Van Ittersum, 2003b). For instance, without the empty bowl as a visual cue to stop eating, subjects ate about 70% more soup than those who were able to view the empty bowl, showing that people use the emptying of food from a bowl or plate, to make decisions about the quantity of food to consume (Wansink et al., 2005).

Proximity and Visibility

Increasing visibility of a food can promote food consumption. For example, Johnson (1974) found that more sandwiches were consumed when wrapped in transparent than opaque packages. However, the effects of visibility of food on food consumption may be dependent on the visual appeal of the food. If a food is visually appealing, then increasing visibility of that food will result in greater energy intake than an unappealing one. Consistent with this idea, Deng and Srinivasan (2013) found that subjects ate more from transparent than opaque packages when given a visually attractive, multi-colored food (fruit loops) (Deng & Srinivasan, 2013) and *less* from transparent than opaque packages when given vegetables. Since vegetables are not as appealing as Fruit Loops in palatability, the authors suggested that presenting less palatable foods (vegetables) in transparent packages may increase salience of the less palatable food, and ultimately decrease consumption (Deng & Srinivasan, 2013).

Although visibility of a palatable food can increase energy intake, results for eating in the absence of visual cues or under low visibility conditions are mixed. For example, some studies showed that blindfolded subjects decreased their caloric intake by 22-24% compared to sighted subjects independent of weight status and portion size (Barkeling, Linne, Melin,& Rooth, 2003; Burger, et al., 2011b; Linne et al., 2002). Similarly, Ross (1970) found subjects consumed less food when eating under dim lighting conditions than when eating under brightly lit conditions (Ross, 1970). Perhaps, subjects who ate in brightly-lit conditions were able to visually monitor their food consumption more effectively than those who ate in the dark (Barkeling et al., 2003; Burger et al., 2011b; Linne et al., 2002; Ross, 1970). On the other hand, Schebeheinne and colleagues (2010) found that restaurant patrons ate more food in the dark than under lighted conditions and Kasof (2002) found that college students consumed *more* food when eating in dim than brightly-lit rooms. However, in Kasof's (2002) study the effects of lighting on eating behaviors depended on the eating pathology of the eater i.e. while restrained eaters ate more under low lighting conditions, the food intake of unrestrained eaters were unaffected by lighting variations.

The effect of visibility of food on food consumption is also mediated by personal preferences for food. Subjects who preferred a stronger cup of coffee drank more coffee under bright than dull rooms, whereas lighting had no effect on those who preferred lighter coffee (Gal et al., 2007 in Spence et al., 2012). In addition, visibility of food on the intention to consume is mediated by the degree of familiarity with the target food. Wansink and colleagues (2012) manipulated the ambiguity of a food product by withholding or providing product information and observing its effects on food consumption in lighted or dark conditions. They found that for highly familiar foods (crackers), acceptance of the product remained the same under both lighted and dark conditions, even when product information was absent. However, when eating the more ambiguous food (beef enchilada), subjects reported less likelihood to consume the food in the dark when product information was absent than present (Wansink et al., 2012).

Visibility of how much food has already been eaten also affects food intake. Diners ate more chicken wings when seated at a table where the empty bones were removed from sight than those seated at a table where the bones were allowed to pile up (Wansink & Payne, 2007). Similarly, when pistachio shells were removed from sight, subjects ate 18% more than when the shells were not removed (Kennedy-Hagan et al., 2011), showing that subjects tend to use foods leftover on the plate as visual reminders of the amount of food consumed to terminate further food intake.

A food is also more visible when nearer to the consumer than when far away. Therefore, increasing proximity to a food source can also increase food intake. College students were more likely to consume dessert when seated closer to the dessert station, than those seated further away (Vanata, Hatch, & de Palma, 2011). Similarly, more desserts were consumed when placed at the front than in the back of a cafeteria (Meyers & Stunkard, 1980) and more foods and beverages were purchased and consumed when placed within arm’s reach that when placed further away (Engell, Kramer, Malafi, Solomon, & Lesher, 1996; Meiselman, Staddon, Hedderley, Pierson, & Symonds, 1994; Musher-Eizenman et al., 2009; Wing & Jeffery, 1979).

Since a more proximate food source is also more visible, Wansink, Painter, and Lee (2006a) manipulated both proximity and visibility of food and observed their independent effects on energy intake. Visibility was varied by serving candy in transparent, open containers or closed, opaque containers and proximity was varied by placing chocolate candy pieces on the desk or further away. The authors found that more chocolate candy was consumed when they were visible and nearer to the consumer than when not visible and placed further from arm's reach, showing that proximity and visibility have an additive effect on energy intake. Even healthy foods are consumed in larger amounts when made more proximate and visible. Privitera and Creary (2012) found that college students ate more fruits when placed in open containers within arm's reach than in closed, opaque containers placed far away. Therefore, both proximity and visibility of a food can additively affect food selection and consumption.

Color

Once a food source is visible, one visual cue from food is its' color. Before ingestion, color can influence judgments of acceptability of a product by affecting expectations of palatability of foods which can ultimately dictate food choice and consumption (Koch & Koch, 2003; Spence, Levitan, Shankar, & Zampini, 2010; Walsh, Toma, Tuveson, & Sondhi, 2001). For example, Morrot, Brochet, and Dubourieu (2001) found that white wine was described with more red wine-related adjectives when colored red, than when left uncolored.

Color can also affect the perceived intensity of odors of solutions when ingested. Zellner and Kautz (1990) and Zellner and Whitten (1999) found that subjects rated colored solutions as more intense in odor than an identical, uncolored solution. The effect of color on the perceived intensity of odors, however, is also dependent on the route of administration of the odor. Odors are detected either directly when volatile odor compounds from food contact olfactory receptors in the nose (called orthonasal olfaction) or indirectly while food is masticated (called retronasal olfaction) (Comeau, Epstein, & Migas, 2001). Odors presented orthonasally (i.e. through the nose via sniffing) were rated higher in intensity than those presented retronasally (i.e. through the mouth via ingestion) when colored than when left uncolored, showing that color's effect on olfaction may be mediated by the route of administration of the odor (Koza, Cilmi, Dolese, & Zellner, 2005).

The type and intensity of color can also affect the perceived taste of a solution. For example, red-colored solutions were rated sweeter than green or uncolored solutions (Johnson, Dzendolet, Damon, Sawyer, & Clydesdale, 1982; Kostyla, 1978; Lavin & Lawless, 1998; Pangborn, 1960; Strugnell 1997) and dark red solutions were rated sweeter than light-red solutions (DuBose et al., 1980; Johnson & Clydesdale, 1982; Lavin & Lawless, 1998). In addition, color affected perceptions of flavor intensity of a product. Subjects rated brown-colored candy labeled "dark chocolate" as more "chocolatey" than green-colored candy labeled "milk chocolate" showing that both color and labeling of a food product can additively affect flavor perceptions (Shankar, Levitan, Prescott, & Spence, 2009).

Tastes mixed in solutions are also more easily discernible when colored than uncolored. Adding red color to a clear solution significantly increased detectability of sweetness (Johnson & Clydesdale, 1982) and adding green significantly increased detectability of sourness (Maga, 1974). The association of red color with sweetness and green with sourness is perhaps due to our learned color-flavor associations that redness indicates ripeness or maturity of a fruit and green color indicates rawness or immaturity (Alley & Alley, 1998; Koch & Koch, 2003; Maga, 1974).

Adding colors to a solution can also aid in flavor identification especially when atypical color-taste combinations are presented. For example, DuBose et al (1980) and Zellner, Bartoli, and Eckard (1991) found that flavored solutions mixed with an atypical color (i.e. a color that is not naturally associated with that flavor such as a cherry-flavored beverage that is colored green) were harder to identify than those mixed with a typical color (i.e. cherry-flavored beverage that is colored red). Therefore, prior experiences with flavors have an influence on the accuracy of flavor-color identifications.

Accuracy of flavor-color identifications, however, occurs outside of conscious awareness. Even when told to ignore color to identify flavor, subjects were more accurate in flavor identification when colored than uncolored, showing that using color as a visual cue to identify a flavor may be an automatic process (Stillman, 1993; Zampini, Sanabria, Phillips, & Spence, 2007). Typical and atypical color-taste combinations influence judgments of palatability of a product. Typically-colored solutions can enhance aroma intensity, flavor intensity, and overall acceptability of foods and beverages more than atypically colored or colorless ones (Christensen, 1983; Du Bose et al., 1980).

In addition to the color of food, the color of the plate or bowl in which food is served can also alter food palatability ratings and intake. For example, a pink-colored food presented on a white plate was judged to be more flavorful, sweeter, and palatable than the same food presented on a black plate (Piqueras-Fiszman et al., 2012). Similarly, hot chocolate served in red cups was liked more than hot chocolate served in white cups (Piqueras-Fiszman, & Spence, 2012) and beverages were rated to be more "thirst-quenching" when served in blue glasses than red, green, or yellow glasses (Guegen, 2003). Food intake may also be altered when served on colored plates. Genschow, Reutner, and Wanke (2012) found that subjects consumed less when pretzels were presented on a red plate rather than on a white or blue plate. The authors hypothesized that red color's frequent association with danger, avoidance, and warning may have translated to food avoidance, and therefore reduced food intake (Genschow et al., 2012). All together, these studies show that color can affect perceived flavor, odor, and taste intensity of foods which can then affect food intake.

Variety

The presence of foods varying in appearance, texture, taste, and flavor can also affect intake. Varied flavors and foods both within a meal (within-meal variety) and across several meals (across-meal variety) were shown to increase energy intake more than monotonous ones in rats (Estornell, Cabo, & Barber, 1995; Louis-Sylvestre, Giachetti, & Le Magnen, 1984; E.T. Rolls, 1979) and humans (Berry, Beatty, & Klesges, 1985; Brondel, et al., 2009; Bucher, Van der Horst, & Siegrist, 2011; Meiselman, de

Graaf, & Lesher, 2000; Norton, Anderson, & Hetherington, 2006; B.J. Rolls, Van Duijvenvoorde, & E.T. Rolls, 1984; Raynor & Epstein, 2001; Spiegel & Stellar, 1990; Zandstra, de Graaf, & Van Trijp, 2000). For example, rats given access to a cafeteria diet (i.e. a variety of palatable, energy-dense foods and flavors) ate more and gained more weight than those given access to plain laboratory chow (Esteve, Rafecus, Fernandez-Lopez, Ramesar, & Alemany, 1994; Louis-Sylvestre et al., 1984; Prats, Monfar, Castella, Iglesias, & Alemany, 1989; B.J. Rolls, Rowe, & Turner, 1980b; Rothwell, Saville, & Stock, 1982; Rothwell & Stock, 1982; Shafat, Murray, & Rumsey, 2009; Treit, Spetch, & Deutsch, 1983). Similarly, humans given varied sandwich fillings, yogurt flavors, and pasta shapes, ate more than those given a single sandwich filling, yogurt flavor, or pasta shape (B.J. Rolls, Rowe, Kingston, Megson, & Gunary, 1982; B.J. Rolls, Rowe, & E.T. Rolls, 1982).

One explanation for the variety effect is the development of sensory-specific satiety. When a meal is consumed to satiety, pleasantness of that meal decreases relatively more than those uneaten (Guinard & Brun, 1998; Nolan & Hetherington, 2009; B.J. Rolls, E.T. Rolls, Rowe, & Sweeney, 1980a; Smeets & Westerterp-Plantenga, 2006). Therefore, when given a variety of foods and flavors, the usual decline in pleasantness after consumption of a single meal is disrupted, resulting in a delay in the development of sensory-specific satiety and an increase in energy intake. Sensory-specific satiety can occur rapidly i.e. within two minutes of consumption and can persist over a 20 minute period (Guinard & Brun, 1998; Hetherington, B.J. Rolls, & Burley, 1989; B.J. Rolls et al., 1980a).

Sensory-specific satiety however, is not limited to the taste sense. Several studies also showed a decline in pleasantness of the *appearance* of eaten foods relative to uneaten foods, called appearance-specific satiety. Rolls, Rowe, and Rolls (1983) found that subjects who ate one of four foods (crackers, cheese, sausage, or water) showed a greater decline in pleasantness of the eaten food than those uneaten and this decline in pleasantness extended to the visual aspects of the meal (Rolls et al., 1983). Similarly, the magnitude of decline in pleasantness was greater for a color of food eaten to satiation than the color of an uneaten food (Rolls et al., 1982). Even when the shape of a food was varied in successive courses, energy intake increased. Rolls et al (1982) showed that when subjects were offered three shapes of pasta, the magnitude of decrease in pleasantness for the eaten shape was greater than the uneaten food shape. Appearance-specific satiety, however, is relatively short-lived because it occurs rapidly (2 min) after consumption, and does not persist after that (Hetherington et al., 1989).

To observe the effects of variety on food intake, however, the foods must be sufficiently dissimilar in several dimensions. For example, Rolls et al (1980a) found that when offered three different flavors of yogurts varying in appearance and texture (hazelnut, blackcurrant, and orange), subjects ate more than when offered only one flavor. But, this so-called variety effect attenuated when the color and texture of yogurts were held constant. In a subsequent experiment, Rolls et al (1980a) found that when subjects were offered strawberry, cherry, and raspberry-flavored yogurt (all pink in color), yogurt intake was not different from those given only a single flavor of yogurt, showing that only varying the flavors of a meal (while keeping the color of the food constant) is not sufficient to increase energy intake. Therefore, presenting foods varying in appearance, texture, odor, and taste of foods may be important to observe the effects of variety on energy intake.

The *perceived* variety of foods can also affect energy intake by changing perceived quantity estimations. When the ingredients of a pasta and vegetable stir-fry meal were presented separately, energy intake increased more than when the ingredients of both foods were mixed together (Levitsky et al., 2012). The authors suggested that segregating food into discrete units increases energy intake by increasing the perceived variety of foods available for consumption. In addition, Redden and Hoch (2009) showed that a varied set of abstract colors and shapes of non-food objects are perceived to be lower in quantity than one that is homogenous. The authors argued that when people see a homogenous set of items, they are able to group them into a single, unified whole making them appear more numerous. This perceived variety effect on quantity judgments also translates to food serving behaviors. Redden and Hoch (2009) found that when subjects were asked to pour enough candy into a bowl to match the quantity in another bowl, subjects given varied colors of candy poured more candy than those given same-colored ones. The authors hypothesized that subjects underestimated the number of multi-colored candy resulting in more candy being poured into the bowl, than when given only single-colored candy.

Segregating a meal into discrete colored units can also provide subtle visual cues to interject “mindless” eating. To demonstrate this idea, Geier, Wansink, and Rozin (2012) gave subjects a tube of either yellow-colored chips (unsegmented) or one with a red-colored chip inserted at regular intervals (segmented). They found that subjects given the segmented snack ate about 50% less than those given the unsegmented snack perhaps because red-colored chips served as visual “stopping points” during the meal that interrupted further food intake. In addition, partitioning a food into discrete lines and shapes can also change the size of bites taken from them. Sobal and Wansink (2007) suggested that chocolate bars partitioned with several lines may be used as visual references to determine the amount of food to be consumed in one mouthful.

Portion Size

One visual cue known to affect the appeal of a food is portion size. Portion size is one of the major contributors of energy intake and Body Mass Index (BMI) in both children and adults (Duffey & Popkin, 2013; McConahy, Smiciklas-Wright, Birch, Mitchell, & Picciano, 2002; Young & Nestle, 2002). Participants rated large portions to be visually more appealing than smaller portions and expressed a greater desire to eat large than smaller portions (Burger, Cornier, Ingebrigsten, & Johnson, 2011a). In addition, people eat more if large portions of food are served rather than smaller portions. In both laboratory and real-life settings, children and adults ate more when snack foods, beverages, sandwiches, and pasta entrees were given in larger portions (Diliberti et al., 2010; Fisher et al., 2003; Fisher & Kral, 2008; Fisher, Yiu, Birch, & Rolls, 2007; Flood, Roe, & B.J. Rolls, 2006; Jeffery et al., 2007; Levitsky & Youn, 2004; B.J. Rolls et al, 2002; B.J. Rolls et al., 2004a, 2004b; B.J. Rolls et al., 2006a, 2006b, 2012; Wansink & Kim, 2005).

Portion size effects on energy intake, however, are mediated by age. B.J. Rolls et al (2000) showed that five-year-old children showed proportional increases in energy intake with incremental increases in macaroni and cheese portions, whereas three-year-old children were unaffected. The authors hypothesized that perhaps young children rely heavily on their internal hunger and satiety signals rather than external (visual) cues such as an empty plate to terminate eating.

Portion sizes of foods may also influence food intake by changing the microstructure of eating. People take large bites when served larger portions of food (Fisher & Kral, 2008). Taking large bites lead to gorging. Gorging on food does not allow sufficient time for the release of regulatory peptides required for the development of satiety resulting in reduced feelings of fullness, increased desire to eat, and increased food intake (Bolhuis et al., 2011; Burger et al., 2011b; de Wijk et al., 2008; Fisher et al., 2003; Fisher, & Kral, 2008; Kissileff et al., 2008; Kral et al., 2001; Weijzen et al., 2009; Zjilstra et al., 2009). Second, people eat faster when given large food portions (Fisher & Kral, 2008). Eating fast does not allow sufficient time for the development of satiation leading to decreased satiation and consequently an increase in food consumption (Azrin et al., 2008; Burger et al., 2011b; Ferster et al., 1962; Kissileff et al., 2008; Martin et al., 2007; Melanson, 2004; Spiegel, 2000; Spiegel, Wadden, & Foster, 1991).

Height

Typically, children and adults use height as a cue when estimating liquid amounts (Anderson & Cuneo, 1978; Piaget, 1952; Raghubir & Krishna, 1999). Piaget (1952) found that children perceive taller glasses to contain more liquid than shorter ones, even when the volume in the two liquids was identical. He attributed this overreliance on height cues to centration bias, a tendency of children to attend to a single dimension to make quantity estimations, while ignoring the rest.

Incorrect quantity estimations due to height biases may in turn, affect the amount of food served and consumed. Wansink and Van Ittersum (2003a) found that subjects poured more liquid into short, wide glasses than tall, narrow ones due to an overestimation of the height of the glass as an indicator of liquid amounts. Height biases in food quantity estimations can affect our expectations of fullness from the food, and ultimately energy intake. Raghubir and Krishna (1999) found that adults perceived a taller glass to contain more liquid than a shorter, wider glass. This overestimation of liquid when given the taller glass resulted in lower perceived volume consumption, lower post-consumption satisfaction, higher actual consumption, and more requests for refills than when given the short, wide glass. The authors hypothesized that when a subjects' expectations do not match actual volume consumed (i.e. liquid in tall glass was overestimated), subjects consume more to compensate for the perceived lower volume consumed (Raghubir & Krishna, 1999).

Shape and Surface Area

The shape of a food can affect the perceived volume of a food (Raghubir & Krishna, 1999). Krider, Raghubir, and Krishna (2001) asked college students to determine if a square or circular pizza was larger. More than 70% of the participants perceived the square pizza to be greater in quantity than the circular pizza. Similarly, the shape of food pieces can also affect food quantity estimations. Wada, Tsuzuki, Kobayashi, Hayakawa, and Kohyama (2007) found that subjects overestimated the weights of foods cut into fine strips and accurately estimated weights of foods cut into blocks. Shapes of food pieces can also affect liking of foods. For example, children liked pictures of vegetables served in the shape of stars than when cut into slices or sticks (Olsen, Ritz, Kramer, & Moller, 2012) and adults preferred pictures of meats cut into pieces than slices (Reisfelt, Gabrielsen, Aaslyng, Bjerre, & Moller, 2009).

The area of a plate occupied by food can also influence judgments of consumption amounts. Food served on larger plates or bowls may be displaced away from the edge of the plate, resulting in a significant underestimation of food (called contrast effects) and foods served on smaller plates displace to the edges of the plate, resulting in a significant overestimation of food (called assimilation) (Van Ittersum & Wansink, 2011). These assimilation and contrast effects, as mentioned earlier, occur due to an optical illusion called the Delbouef illusion and is based on the idea that the presence of one circle may change the perceived size of another circle (Nicolas, 1995). This visual illusion affects quantity estimations and the amount of food served and consumed. For example, Van Ittersum and Wansink (2011) found that subjects poured less soup into a smaller than larger bowl due to overestimation of the diameter of the smaller bowl. This overestimation of foods served in smaller bowls, may also explain why the amount of food served in smaller bowls is less than the amount of food served in larger bowls, resulting in less energy intake from smaller than larger bowls (Van Ittersum & Wansink, 2011; Wansink et al., 2006b).

Size and Number

In addition to shape and surface area, the size of food pieces can affect liking of a food. Both rats and nonhuman primates show a preference for larger than smaller food pieces (Boysen, Bernston, & Mukobi, 2001; Menzel, 1961; Menzel & Davenport, 1962; Menzel & Draper, 1965; Yoshioka, 1930). Yoshioka (1930) found that rats preferred larger over smaller sunflower seeds even though the larger seeds contained less food overall. Moreover, Yoshioka (1930) found that this preference diminished when seeds were eaten in darkness, showing that size is an important visual cue used to regulate food intake in rats.

Varying the size of food pieces have been shown to affect energy intake in humans. Spiegel et al (1989) developed solid food units (SFU's), spirals of bread with varied fillings to accurately measure the rate of ingestion of a single, solid food. In this type of procedure, both obese and normal subjects were instructed to place one SFU in the mouth at a time, so that the amount and rate of ingestion can be measured while keeping bite size constant. The authors found that when subjects were given an unlimited number of solid food units of varying sizes, subjects ate faster and also ate fewer solid food units as the size of the units increased (Spiegel et al., 1989).

A fixed portion of food varying in number and size can also affect quantity estimations. Consumers in a marketing study judged a snack packet with an image of 15 pretzels to contain a greater number of pretzels than a package containing an image of three pretzels, even though the actual quantity of pretzels in the package were the same (Madzharov & Block, 2010). In addition, Scisco et al (2012) found that subjects perceived a 16-piece Jell-O portion to contain more food than a nine-piece Jell-O portion.

Varying the size and number of pieces can also affect the amount of food that is consumed. Nisbett and Storms (1972), varied the size and number of food pieces and found that subjects ate more when given four, quartered sandwiches (16 pieces) than the same sandwiches cut into 32 bite-sized pieces. The authors hypothesized that quartered sandwiches may have resembled "meals" that are typically eaten in large amounts, whereas, bite-sized pieces may have resembled "snacks" that are typically eaten in smaller amounts. Similarly, Marchiori and colleagues (2011) found that adults ate more when served 10 large candies, than the same candies cut into 20 bite-sized pieces (Marchiori et al., 2011) and that children ate more when served 18 large cookies than those cut into halves (i.e. 36 bite-sized pieces) (Marchiori et al., 2012). Weijzen et al (2008) found that subjects ate six large candy bars significantly faster and in larger amounts than the same amount of candy cut into 66 bite-sized pieces. The authors hypothesized that increased energy intake from the large chocolate candy bars may have increased the size of bites taken from the food resulting in shorter exposure to food in the mouth. Short oro-sensory exposure to food elicits lower satiation signals, and consequently facilitates an increase in energy intake (Bolhuis et al., 2011; Cecil, Francis, & Read, 1998, 1999; de Wijk et al., 2008; Forde et al., 2013a; French & Cecil, 2001; Kissileff et al., 2008; Kral et al., 2001; Raynor & Epstein, 2000; Weijzen et al., 2009; Wijlens et al., 2011; Zijlstra et al., 2009). Taken together, all these studies show that varying the size and number of pieces can affect food intake either by changing our expectations of satisfaction from the food or indirectly by changing eating behaviors.

In the aforementioned studies, however, size varied along with the number of food pieces as the total amount of food was held constant. The portion with the smaller pieces also contained a greater number of pieces than the portion with the larger food pieces i.e. 16 large sandwich pieces were cut into 32 bite-sized ones (Nisbett & Storms, 1972), 10 large candy were cut into 20 small pieces (Marchiori et al., 2011), and 18 large cookies were cut into 36 small pieces (Marchiori et al., 2012). Therefore, *number* of food pieces is also an important visual cue affecting food intake.

The effects of number of food pieces, independent of size, have been studied extensively in animals. Wolfe and Kaplon (1941) found that chickens ran significantly faster for a popcorn kernel cut into quarters than one left whole, showing multiple pieces of food were more rewarding than a single piece. Similarly, rats ran faster for multiple

(4-22) pellets of food than an equicaloric, single pellet of food (Amsel et al., 1968; Campbell et al., 1972; E.J. Capaldi et al., 1989; McCain, 1969; Traupmann, 1971) and preferred a multiple-piece (four, 75 mg pellets) over an equicaloric, single piece of food (300 mg) in a T-maze. Humans also prefer and find a multiple-piece portion to be more satiating than a single piece one. In an unpublished experiment in our lab, we found that subjects preferred and also ate less of a multiple-piece serving than a single-piece one. In addition, food intake following the multiple-piece serving was lower than the single-piece serving.

Since both animals and humans find a multiple-piece food portion to be more rewarding than a single-piece one, this preference may have its' basis in evolution. Both rats and humans are mammals, share ancestral origins, and an omnivorous pattern of feeding (Rozin, 1976). Thus, any similarities in rat and human feeding behaviors may reflect shared evolutionary traits that may be conserved due to their high adaptive value. In the natural environment, the physical quantity of a stimulus may be strongly correlated with number. Therefore, numerosity of a stimulus may be used to make quantity estimations in both animals and humans (Pelham, Sumarta, & Myakovsky, 1994). Many studies show that humans and nonhuman primates judge quantities based on number in quantitative discrimination tasks (Barth, Kanwisher, & Spelke, 2003; Gathercole, 1985; Hanus & Call, 2007). Therefore, our study comparing four pieces of food to one in humans and 30 pieces to one in rats, suggests that number itself is an important criteria in food quantity discriminations that can ultimately affect food selection in both animals and humans.

A multiple-piece portion of food may also activate common brain regions and neurotransmitters associated with reward in animals and humans. There are two known dopaminergic pathways for reward processing in the brain: the mesocorticostriatal and mesolimbic pathways (Bressan & Crippa, 2005). The mesocorticostriatal pathway extends from the ventral tegmental area (VTA) to the prefrontal cortex. The mesolimbic pathway extends from the VTA in the substantia nigra to the ventral striatum which in turn, receives projections from the amygdala, hippocampus, and prefrontal cortex (Berridge & Robinson, 1998; Bressan & Crippa, 2005; Robbins & Everitt, 1996). The ventral striatum contains the nucleus accumbens, a region known to mediate the reward value of natural reinforcers like food and drugs (Berridge & Robinson, 1998; McClure, York, & Montague, 2004; Morton, Cummings, Baskin, Barsh, & Schwartz, 2006; Robbins & Everitt, 1996). Koch, Schmid, and Schnitzler (2000) and Salamone and colleagues (1991) showed that a depletion in dopamine levels in the nucleus accumbens via the administration of dopamine (D1 and D2) receptor antagonists, reduces the reward value of a preferred food and shifts rat's eating behaviors towards less preferred foods (lab chow). The authors suggested that dopamine's role in the nucleus accumbens is mostly to potentiate the rewarding effects of a food, and not inhibit the general motivation to eat.

The processing of reward in the nucleus accumbens is also dependent on afferent projections from limbic system structures such as the amygdala and hippocampus that mediate the incentive and hedonic value of a food reward and guide eating behaviors (Tracy, Jarrard, & Davidson, 2001). For instance, LaBar et al (2001) found that human subjects showed greater activation in the amygdala, parahippocampal gyrus, and associated corticolimbic structures when exposed to food than non-food pictures in a hungry than satiated state. The authors suggested that visual information from food may be influenced by the nutritional state of the organism possibly through mediation of the amygdala. Therefore, multiple pieces of food may be more rewarding than a single piece possibly through mediation of visual information from food by the amygdala and other corticolimbic structures associated with reward, which ultimately facilitates food selection and consumption in animals and humans.

Since multiple pieces of food are more rewarding than a single piece in both animals and humans, we hypothesized that perhaps the multiple-piece portion was perceived to be greater in quantity as they take up a larger surface area than the single-piece one. This notion was further tested in a subsequent study in our lab in college students, where we varied the surface area occupied by a five-piece chicken portion by scattering the food pieces on a plate or clustering them together. We found that subjects given the scattered chicken portion ate significantly fewer calories from the chicken portion as well as from a subsequent test meal than those given the clustered chicken portion, showing that the spread of a food portion on a plate is an important visual cue that can affect food quantity estimations and ultimately food consumption volumes. In animals, however, a multiple-piece portion taking up a larger surface area was found to be less rewarding than one taking up a smaller surface area. An unpublished study in our lab found that rats trained on a T-maze preferred a 300 mg portion (30, 10 mg pieces) clustered together than the same portion scattered.

Differences in the rewarding effects of surface area occupied by food in rats and humans may be suggestive of the role of varying dietary experiences between the two species. Although rats and humans share many commonalities in eating behaviors and an omnivorous pattern of feeding, human food selection and consumption is subject to multiple socio-cultural and higher-order cognitive processes (Rozin & Kalat, 1971). For example, one important higher-order cognitive process that affects food intake in humans is memory. Rozin, Dow, Moscovitch, and Rajaram (1998) showed that patients suffering from memory loss will initiate a second and third meal within 10-20 minutes of consuming the first meal. Perhaps, then the memory of consuming a perceptually large meal (scattered portion) may have reduced further food intake in humans.

Animal food selection, on the other hand, may be considered in the context of the problem in which it may have evolved (Rozin & Kalat, 1971). In the natural environment, a food occupying a larger surface area may not be beneficial for rats as this would require greater expenditure of time and energy. Since clustered food pellets are already gathered, less time and effort may be required to eat them, resulting in greater preference for clustered over scattered food pellets. Therefore, preference for a food portion occupying a smaller area may reflect a behavioral trait that is adaptive in nature. This is not to say however, that evolutionary history of species can provide an explanation for *all* behavior. But, it may provide one possible framework to understand the ‘whys’ or ‘hows’ of an animal’s behavioral repertoire.

Future Directions

Most studies largely overlook the effects of visual cues and focus more on taste of food as an important sensory influence on food intake. Although color has been extensively researched in the literature, few studies have measured other aspects of the appearance of a meal. All the research described above show that visual cues such as portion size, visibility, color, proximity, perceived and actual variety, size of food pieces, number of food pieces, shape, and surface area occupied by food can all affect food intake either via changes in acceptability of a food and feeding behaviors, changes in perceptions of food quantity, or both.

Despite all the information about different visual cues on food intake, however, there are still some unanswered questions in the literature. First, in light of the evidence that large portions of food increase energy intake, the food industry advertised single-serving packages of food to encourage portion control. But, the relationship between single-serving food portions and energy intake in the laboratory remains unclear (Hill, 2009). For instance, Stroebele Ogden, and Hill (2009) showed inconsistent effects of 100 kcal versus regular-sized snack packages on energy intake over a two-week period and Raynor, Van Walleghen, Niemeier, Butryn, and Wing (2009) found that consumption from single-serving packages at breakfast was lower than from standard packages in participants recruited for a weight loss program. The amount of food consumed from single-serving packages is also dependent on individual characteristics of the consumer. For example, Wansink, Payne, and Shimizu (2011) found that while normal-weight consumers were unaffected by package size, overweight consumers ate about 25% less when given four 100 kcal packages of food versus a single, 400 kcal package. In addition, individuals with greater self-control and lower self-esteem consumed significantly more food from smaller than larger, standard packages of foods (Argo & White, 2012; Coelho do Vale, Pieters, & Zeelenberg, 2008).

One important factor affecting food intake in the aforementioned studies on single-serving packages is the visual aspect of the food itself. A food portion packaged into single 100 kcal packages eliminates the visual cues used in monitoring food intake when food is eaten directly from the package. Perhaps, 100 kcal packages may reduce intake if served on a plate or bowl so that they can be used as visual references for the amount of food consumed. Second, when a package is labeled “100 kcal” it creates a health halo bias that if something is labeled low-calorie or healthy, more can be consumed (Provencher, Polivy, & Herman, 2009). Therefore, more research needs to be undertaken to examine the role of visual cues on the effect of single-serving packages on energy intake.

Second, manipulations of visibility of food either via changes in lighting conditions or by blindfolding subjects have shown inconsistent results. Although palatability and familiarity of food have been shown to interact with lighting and visibility, the moderating influence of other factors have not been investigated. The type of food i.e. highly palatable or nutritious foods may also moderate the influence of visibility on food intake. Deng and Srinivasan (2013) found that while intake of palatable foods increased when packaged in transparent wrapping, the intake of less palatable foods like vegetables decreased. Therefore, more studies need to investigate the effects of visibility on food intake when the palatability of the target food is varied.

Third, it is surprising that very few studies have investigated the effects of shape of foods on energy intake. Most studies on portion size have focused on amorphous foods (Fisher & Kral, 2008; Raghubir & Krishna, 1999; Van Ittersum & Wansink, 2011; Wansink et al., 2006; Wansink & Van Ittersum, 2003). However, the shape of food cut into discrete sizes and shapes and the amount of room taken up by food can also affect quantity estimations, expectations of palatability of food, and ultimately food intake

(Krider et al., 2001; Olsen et al., 2012; Reisfelt et al., 2009; B.J. Rolls et al., 1982; Wada et al., 2007). In addition, the shape of a food may also change feeding behaviors by changing the size of bite or perception of intensity of food in the mouth. In fact, desserts with added odors were consumed in smaller bites than those presented with no odors due to the larger quantity of aroma molecules present in larger bites (de Wijk, Polet, Boek, Coenraad, & Bult, 2012; Ruijschop et al., 2011). Perhaps, then the shape of food pieces may also change the intensity of tastes and odors experienced in the mouth and ultimately affect food intake.

Fourth, much of the literature on the effects of surface area occupied by a portion of food on food intake is conducted on amorphous foods or foods that take the shape of the plate or bowl in which it is served (Fisher & Kral, 2008; Raghubir & Krishna, 1999; Van Ittersum & Wansink, 2011; Wansink et al., 2006; Wansink & Van Ittersum, 2003a). With the exception of our study, no study has determined the effects of the surface area occupied by a non-amorphous portion of food and its effects on eating behaviors and energy intake.

Lastly, studies investigating the size and number of pieces occupied by food pieces are largely limited. Except for a few studies on the effects of food item size on energy intake, we still don’t know if cutting up foods into small pieces or presenting food in smaller pieces decreases intake in both obese and normal-weight subjects and in restrained and unrestrained eaters.

Practical Applications

Given that varied visual cues can affect food intake, changing the appearance of a food may be used to both initiate and facilitate the consumption of healthy foods in children. Zampollo and colleagues (2012) suggested that children prefer varied colors of foods on their plates and Olsen et al (2012) found that children prefer fruits and vegetables cut into different figures to those cut into slices or sticks. Perhaps this can be used as one strategy to increase fruit and vegetable intake in children. Most children fail to meet recommendations for fruit and vegetable intake in the U.S (Lorson, Melgar-Quinonez, & Taylor, 2009). Consumption of fruits and vegetables is beneficial for the prevention of chronic diseases such as cancer, cardiovascular disease, and obesity (Birt, Hendrich, & Wang, 2001; Epstein et al., 2001; McCrory et al., 1999; Ness & Powles, 1997). Therefore, parents and teachers may consider serving foods in an attractive fashion to encourage the intake of healthy foods in children.

Varying the number and surface area occupied by a portion of food can decrease energy intake. Unpublished studies in our lab showed that not only can cutting food in small pieces decrease energy intake from that portion but also from a buffet of palatable foods given 20 min later. Similarly, spreading a multiple-piece portion of food on a plate may reduce food intake more than one that is clustered in the center. Therefore, cutting up energy-dense foods into smaller pieces or spreading a multiple-piece portion of food on a plate may be beneficial for dieters who wish to regulate their food intake.

Leaving foods whole may also be used as one strategy to increase food intake. Anorexics have been shown to cut their food into smaller pieces and spread their food portion on the plate to make it look like more food (Garner & Garfinkel, 1979). Therefore, recovering anorexics may benefit from leaving foods whole to increase their consumption of these foods. Less than 10% of Americans meet the daily recommendations for fruit and vegetable intake (Kimmons, Gillespie, Seymour, Serdula,

& Blanck, 2009). Therefore, serving healthy foods whole may also increase intake in both children and adults. Future studies should investigate the effects of number of pieces of food on the intake of healthy foods in both children and adults.

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Table 1

Weights, calories, and macronutrient content of foods served in Experiment 1

Foods	Weight(g)	Energy (kcal)	Fat (g)	Protein (g)	Carbohydrate (g)
Tyson's fully-cooked chicken breast	23.3	50	2	3.8	4.2
Test meal					
Turkey sandwich	29	50	1.0	4.5	5.7
Crackers with ham and cheddar cheese	30	50	4.3	4.7	4.5
Roasted potatoes	79	65	1.5	1	12
Peanut butter and jelly sandwich	21	50	0.6	3.2	8
Carrots and celery with fat-free ranch dressing	80	50	1	0.6	10
Mozzarella cheese sticks	15	50	3	2.1	3.8

Table 2

Weights, calories, and macronutrient content of foods served in Experiment 2

Foods	Weight (g)	Energy(kcal)	Fat (g)	Protein (g)	Carbohydrate (g)
Bagel with cream cheese	82.1	200	5.5	7.3	30.7
Test meal					
Turkey sandwich	84	200	5	17	22
Crackers, ham and cheese	157	200	10.2	8	19
Potato salad	135	200	10	3	24.6
Chocolate cupcake	57	200	10	1	26
Pasta	117	200	12	8	15
Mozzarella cheese sticks	57	200	12	7	16
Carrots and celery with ranch dressing	130	150	17.8	0	10

Table 3

Means and standard errors for pleasantness ratings, time spent eating, and eating rate of the bagel as a function of number of bagel pieces served in Experiment 2

Attributes	Four-piece bagel		Single, uncut bagel	
	M	*SEM*	*M*	*SEM*
Pleasantness ratings	51.5	±2.16	49.4	±2.08
Eating duration (sec)	254.69	±6.09	255.42	±5.93
Eating rate (g/sec)	.71	±.02	.77	±.02

Note. There were no significant differences in pleasantness ratings, eating, duration, and eating rate between the four-piece and single, uncut bagel.

Table 4

Weights, calories, and macronutrient content of foods served

Foods	Weight (g)	Energy(kcal)	Fat (g)	Protein (g)	Carbohydrate (g)
Chicken	65	85.1	1.9	15.5	1.5
Test meal					
Chicken nuggets	81	180	9.8	13	10
Crackers with turkey and cheddar cheese	24	65	2.3	4	7
Peanut butter and jelly sandwich	54	175	6	5.3	25.2
Chocolate cupcake	45	160	6	1	25.5
Small pepperoni pizza	41	100	4.3	4.8	10.5
Mozzarella cheese sticks	28	90	5.1	4	7

Table 5

Means and standard errors for pleasantness ratings, time spent eating, and eating rate of the chicken serving as a function of the surface area occupied by pieces

Attributes	Scattered chicken portion		Clustered chicken portion	
	M	*SEM*	*M*	*SEM*
Pleasantness ratings	47.15	±3.12	3.12	±3.92
Eating duration (sec)	157.51	±8.08	155.08	±6.10
Eating rate (g/sec)	1.11	±.05	1.15	±.05

Note. There were no significant differences in pleasantness ratings, eating duration, and eating rate between the scattered and clustered chicken portions.

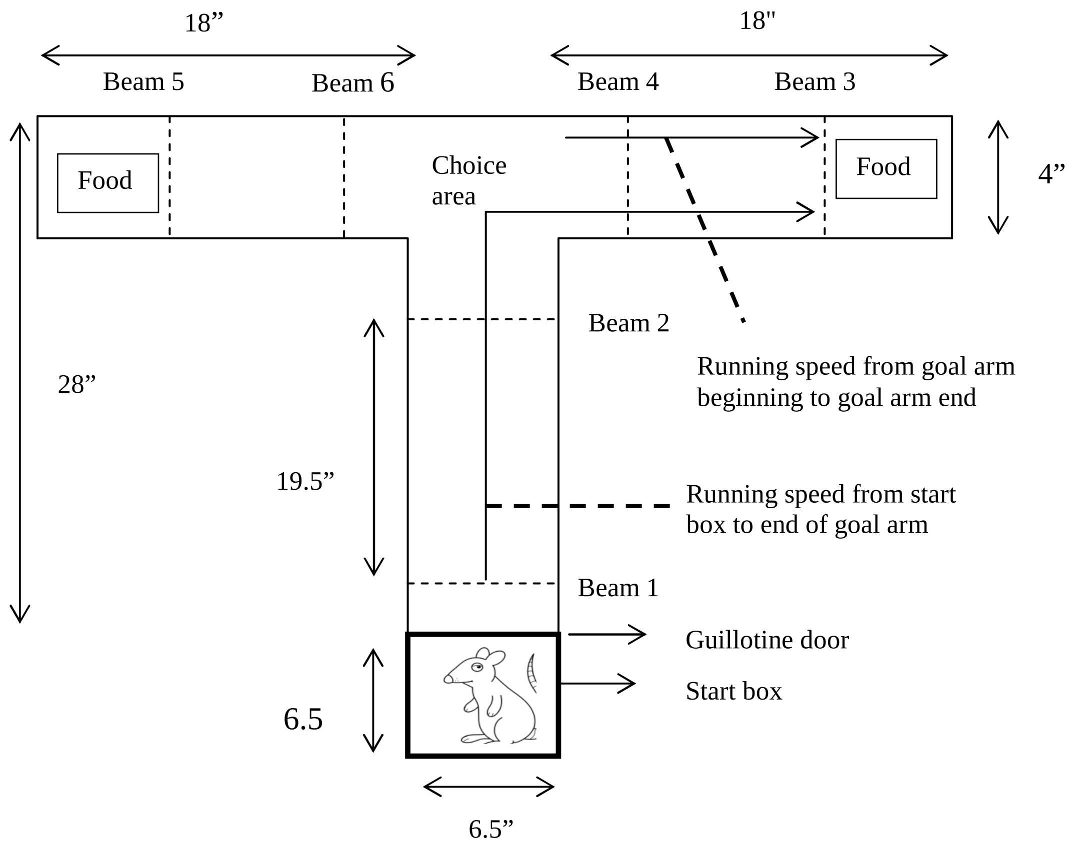

Figure 1. A diagram of the T-maze used in Experiments 1 and 2.

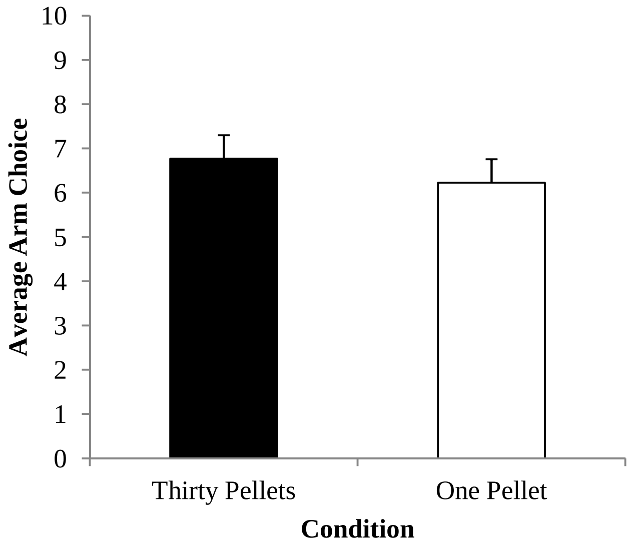

Figure 2. Average choice of arm baited with the multiple pellets and single pellet of food in a T-maze in all free trials during training in Experiment 1. There was no significant difference in arm choice during training.

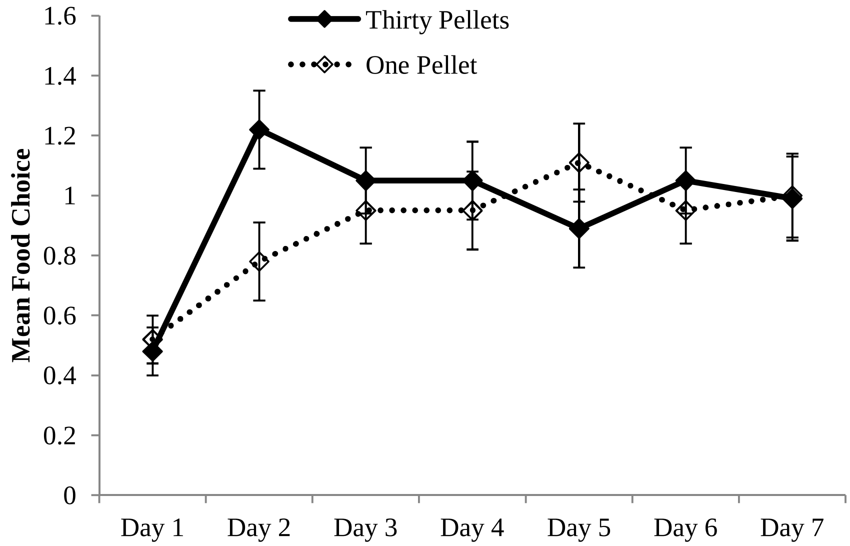

Figure 3. Average choice of arm baited with the multiple and single pellet of food by days in all free trials during training in Experiment 1. Choice of the multiple and single pellet of food did not vary over days.

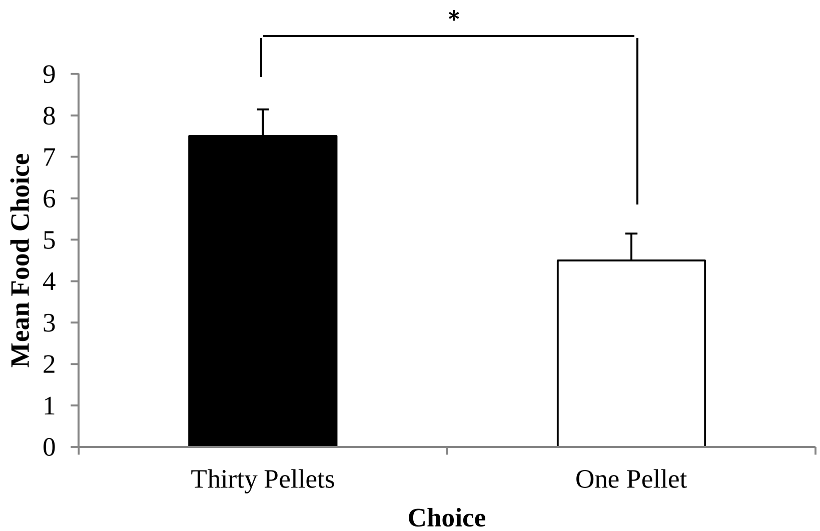

Figure 4. Average choice of arm baited with the multiple pellets and single pellet of food in testing in Experiment 1. * indicates a significant difference. Vertical lines represent standard error.

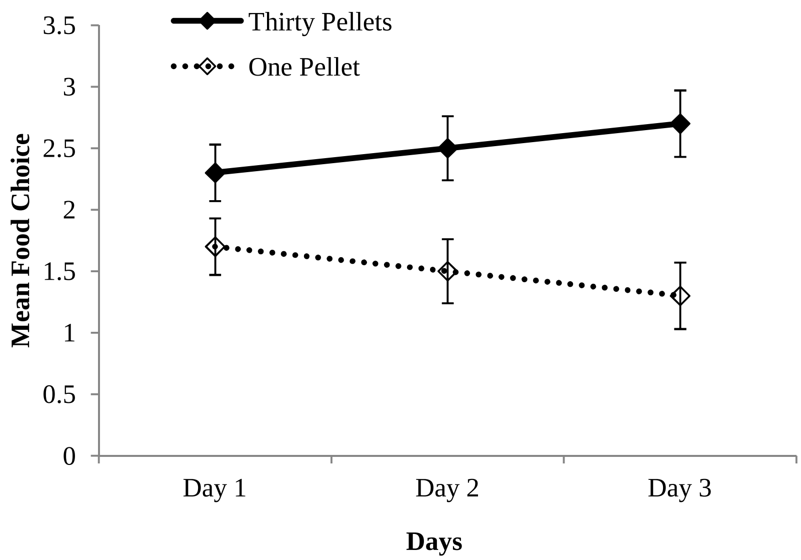

Figure 5. Average choice of arm baited with the multiple and single pellet of food by days in all testing in Experiment 1. Choice of the multiple and single pellet of food did not vary over days.

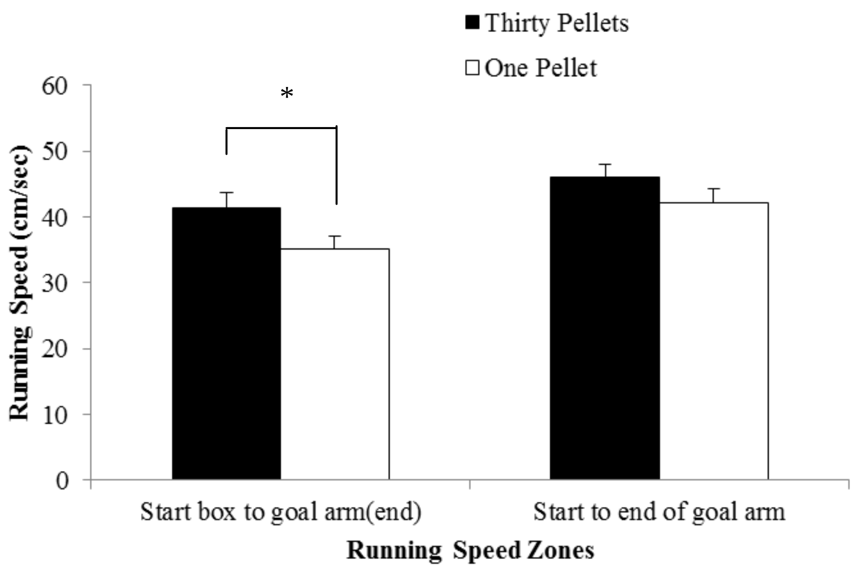

Figure 6. Average running speed (cm/sec) for arm baited with the multiple pellets and single pellet of food in testing in Experiment 1. * indicates a significant difference in running speed between the multiple and single pellet of food. Vertical lines represent standard error.

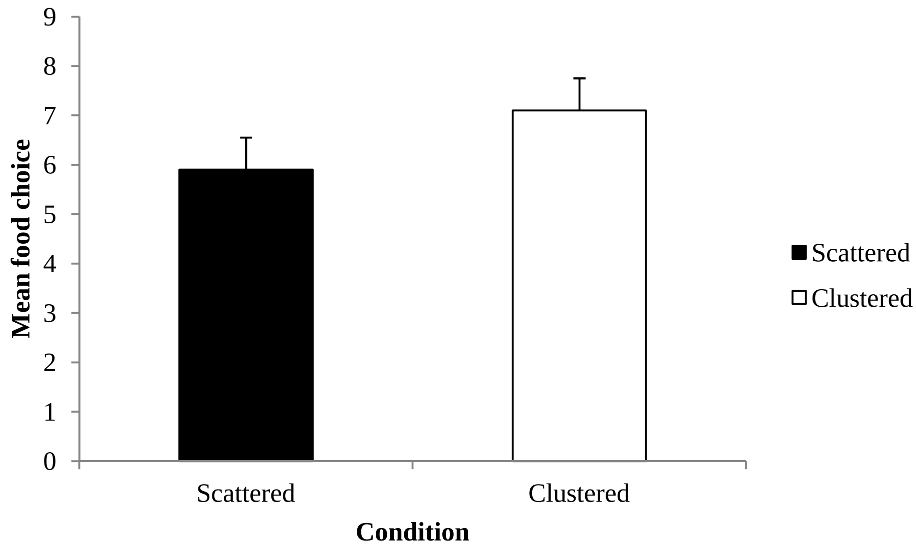

Figure 7. Average choice of arm baited with the scattered and clustered food pellets in a T-maze in all free trials during training in Experiment 2. There was no significant difference in food choice during training. Vertical lines represent standard error.

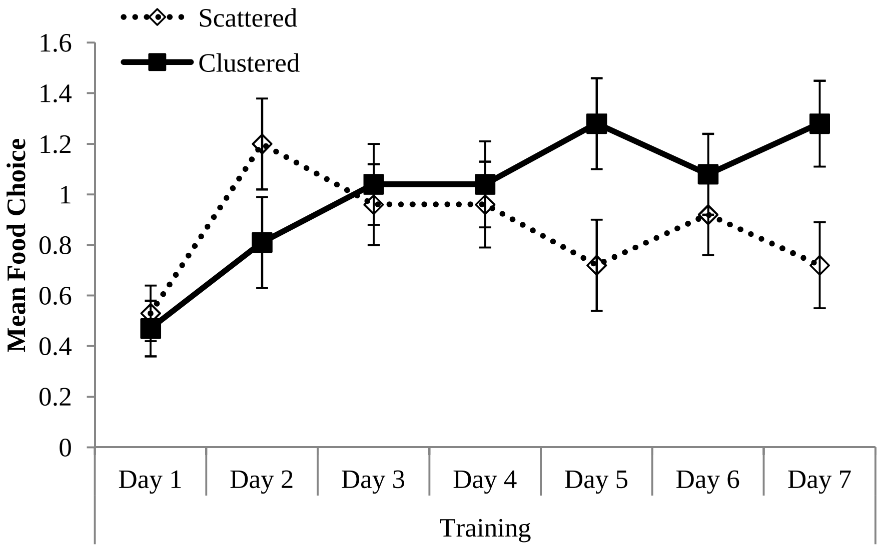

Figure 8. Average choice of arm baited with the scattered and clustered food pellets in all free trials during training in Experiment 2. Choice of the scattered and clustered food pellets did not vary over days.

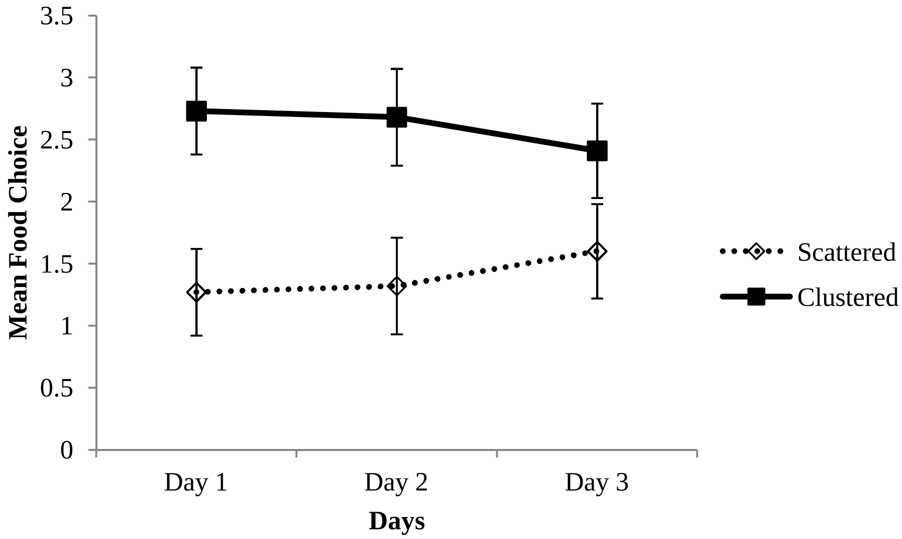

Figure 9. Average choice of arm baited with the scattered and clustered food pellets in testing in Experiment 2. Choice of the scattered and clustered food pellets did not vary over days.

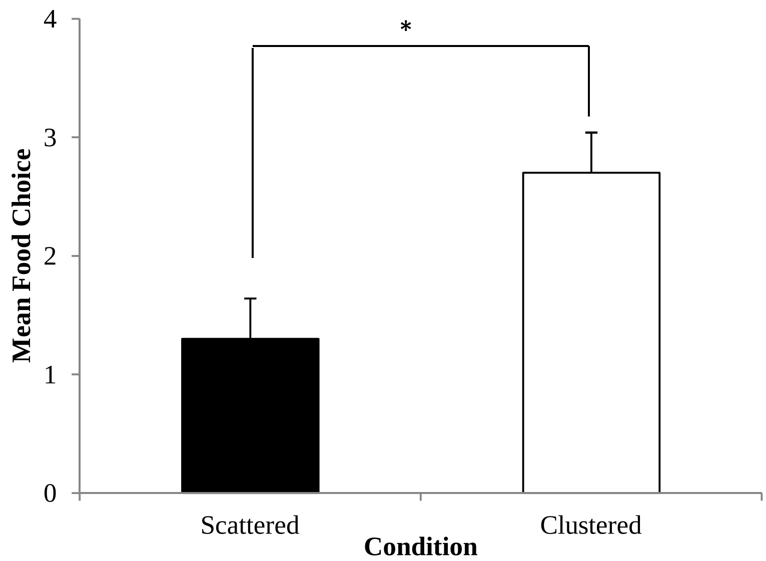

Figure 10. Average choice of arm baited with the scattered and clustered food pellets only on Testing Day 1 in Experiment 2. * indicates a significant difference. Vertical lines represent standard error.

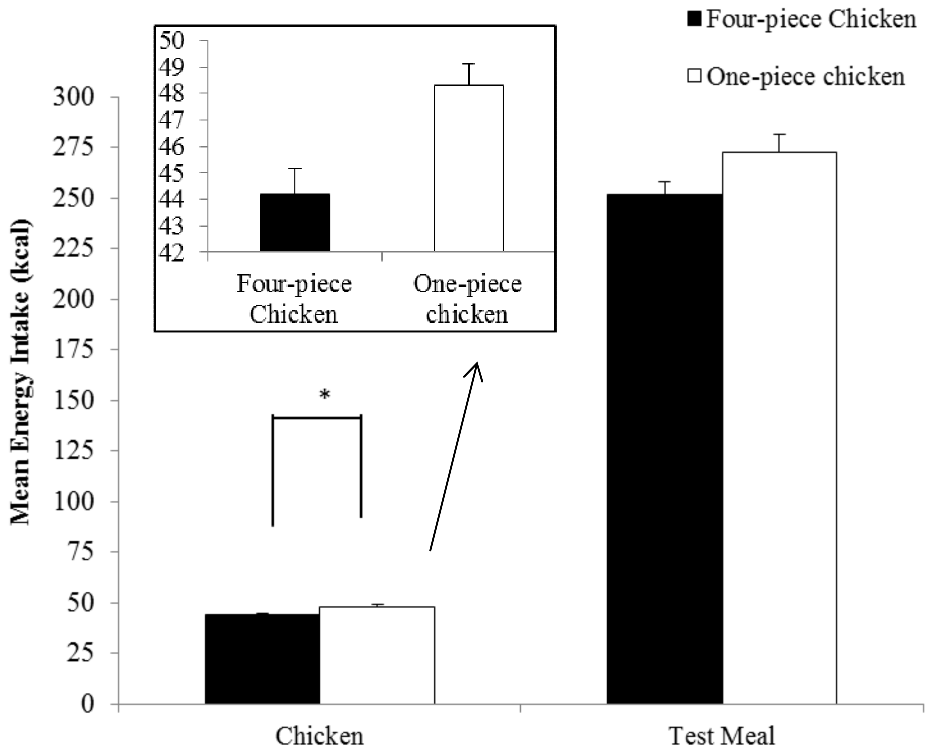

Figure 11. Mean consumption (kcal) of the chicken portion and test meal by subjects who chose the four-piece and single-piece chicken in Experiment 1. Mean intake of the four-piece chicken portion was significantly lower than the single, uncut portion. Mean test meal intake after the multiple pieces was marginally lower than the single-piece chicken portion. * indicates significant differences in energy intake between subjects who chose the four-piece and one-piece chicken portion. Vertical lines represent standard error.

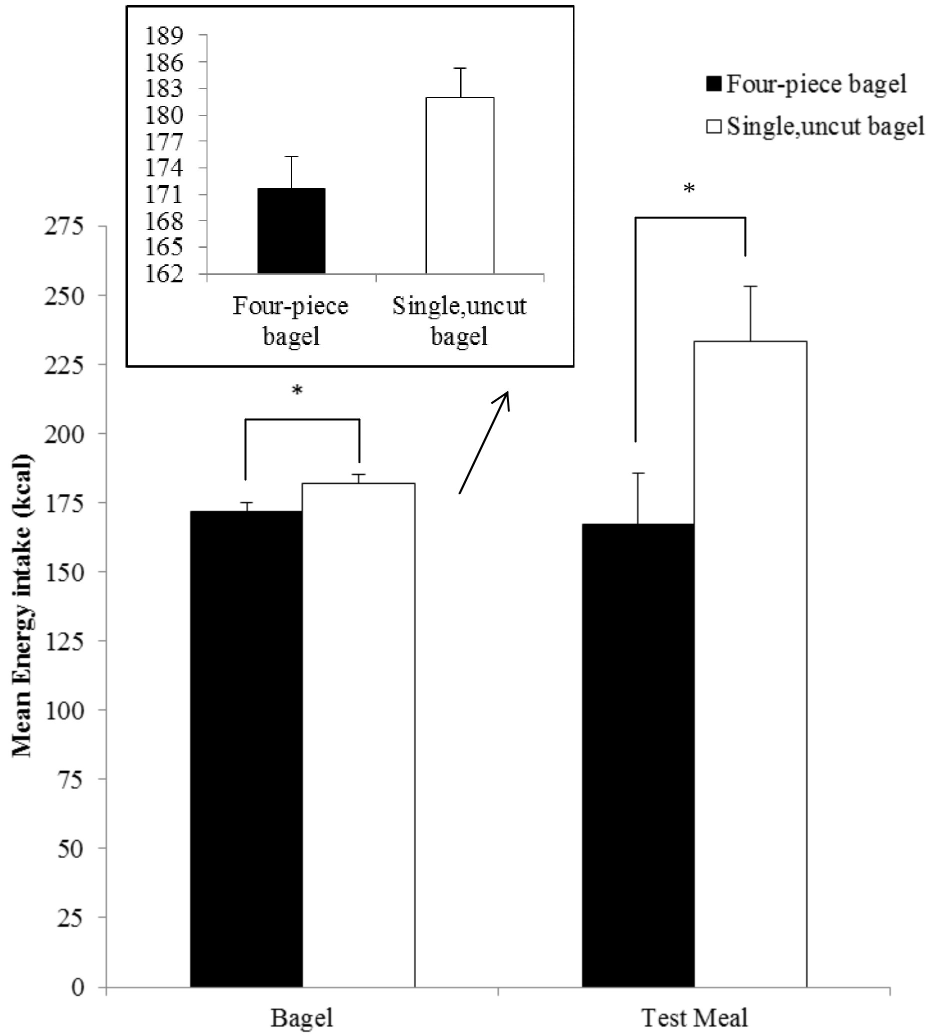

Figure 12. Mean consumption (kcal) of the bagel and test meal by subjects given the four-piece and single, uncut bagel in Experiment 2. Mean intake of the four-piece bagel was significantly lower than the single, uncut bagel. Mean test meal intake following the four-piece bagel was significantly lower than that following the single, uncut bagel. * indicates a significant difference in energy intake as a function of number of bagel pieces served. Vertical lines represent standard error.

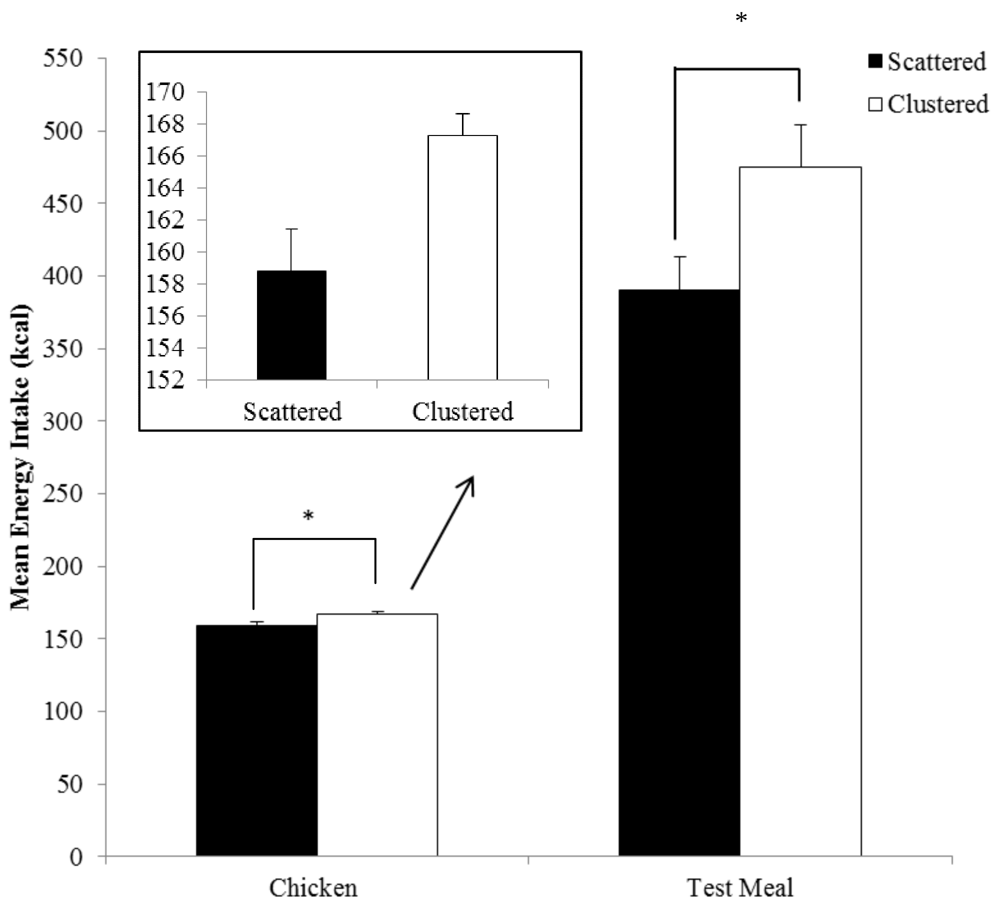

Figure 13. Mean consumption (kcal) of the chicken serving and test meal by subjects given the scattered and clustered pieces. Mean intake of the scattered chicken portion was significantly lower than the clustered chicken portion. Mean test meal intake following the scattered chicken portion was significantly lower than the clustered chicken portion. * indicates significant differences in energy intake as a function of the surface area occupied by the food pieces. Vertical lines represent standard error.