

EFFECTS OF MONOSODIUM GLUTMATE ON OBJECTIVE
AND PERCEIVED SATIETY AMONG
7- TO 9- YEAR OLD CHILDREN

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ABSTRACT

Background: Monosodium glutamate (MSG) imparts umami taste associated with proteins and is known to act as a flavor-enhancer. Several adult studies and a recent study of infants suggests that MSG may also have beneficial effects on appetite by promoting satiety. This research is the first to assess effects of MSG on perceived and objective satiety among children.

Methods: A between-subjects design (MSG+ or MSG-) was used to evaluate the effect of adding MSG to a soup pre-load on subsequent satiety among children aged 7-9 years. Children were randomly assigned to experimental condition (MSG+ or MSG-). Perceived hunger and fullness were evaluated prior to and following consumption of the pre-load using a Visual Analogue Scale (VAS). Objective satiety was assessed using weighed food intake methods at an *ad libitum* meal following the preload.

Results: Children in the MSG+ condition showed greater decreases in perceived hunger following the consumption of the pre-load than children in the MSG- condition ($F=4.05$, $p<0.05$). Total energy intake at the *ad libitum* meal did not vary by MSG condition.

Conclusions: The results of this study provide evidence that MSG may reduce perceived hunger among 7- to 9- year old children.

I dedicate this thesis to my family and soon-to-be husband, Michael,
for their unwavering love and support in
all I have set out to accomplish.

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CHAPTER 1

INTRODUCTION

Monosodium L-glutamate (MSG) is a common food additive that imparts umami taste and is known to act as a flavor-enhancer (Bellisle, 1998; Yeomans, Gould, Mobini, & Prescott, 2008). MSG has been shown to improve palatability of foods (Bellisle et al., 1991; Rogers & Blundell, 1990; Yeomans et al., 2008) leading to its investigation as a potential stimulant of appetite (Essed et al., 2009; Mathey, Siebelink, de Graaf, & Van Staveren, 2001; Yeomans, 1996). Appetite can be explained using three main dimensions: hunger, satiation, and satiety. Hunger is the subjective feeling that one feels that leads them to begin eating (A. J. Hill, Magson, & Blundell, 1984), satiation is referred to as the process that occurs while food is being consumed that triggers the body to stop eating (J. Blundell et al., 2010; J. E. Blundell & King, 1996) and satiety can be regarded as the process related to the suppression of intake after eating (J. Blundell et al., 2010; J. E. Blundell & King, 1996).

Appetite can be influenced by situational eating cues and prior experiences (i.e. learning). One type of learning occurs as the sensory characteristics of a food becomes associated with its post-ingestive effects on consumption (Bertenshaw, Luch, & Yeomans, 2013; Griffioen-Roose, Mars, Finlayson, Blundell, & de Graaf, 2011; Yeomans & Chambers, 2011). Given that protein sources impart umami taste, it is possible that MSG-enhanced foods influence appetite through associations with sensory cues typically associated with proteins (Luscombe-Marsh, Smeets, & Westerterp-Plantenga, 2008).

Experimental studies of institutionalized elderly have shown that the addition of MSG to foods served in the cafeteria increased food acceptability and food intake of those foods (Bellisle et al., 1991; Schiffman, 1998). In a randomized cross-over study, the addition of MSG to a high-protein meal increased energy intake at a second course meal compared to the high-protein meal without MSG (Luscombe-Marsh, Smeets, & Westerterp-Plantenga, 2009). However, more emerging research also indicates that MSG may actually suppress appetite and enhance satiety (Masic & Yeomans, 2013). Three experimental studies of adults have shown that the addition of MSG to pre-loads resulted in a decreased *ad libitum* intake at a subsequent test meal, and a relative decrease in perceived hunger, suggesting that MSG increases satiety (Carter, Monsivais, Perrigue, & Drewnowski, 2011; Masic & Yeomans, 2014; Rogers & Blundell, 1990). In the only non-adult study to date, Ventura et al., investigated the effects of free glutamate in cow's milk formula on satiety and satiation in 30 healthy infants. Infants were served three pre-loads, 1) cow's milk formula (CMF) 2) extensive protein hydrolysate formulate (ePHF) and 3) cow's milk formula with added free glutamate (CMF+glu) over the course of three weeks to examine how each affected intake at a subsequent test formula meal (CMF). The amount of formula infants consumed to satiation during the first formula meal varied based on the type of formula they were fed. Infants consumed significantly less CMF+glu and ePHF and showed greater levels of satiety compared to CMF, suggesting that free glutamate enhanced formulas promotes satiation quicker (Ventura, Beauchamp, & Mennella, 2012).

Whether MSG has effects on satiety in children has yet to be studied. The purpose of this research was to experimentally evaluate the effects of MSG on perceived and objective satiety in 7- to 9- year olds.

CHAPTER 2

BACKGROUND

Obesity is one of the largest public health concerns of the 21st century. Obesity affects children as well as adults. Among children and adolescents aged 2- to 19- years, 16% have a BMI-for-age percentile that classifies them as obese (Ogden, Carroll, Kit, & Flegal, 2014). Obesity is fundamentally a problem of energy imbalance. As defined by Hill et al, the three main components of energy balance are energy intake, energy expenditure, and energy storage (J. O. Hill, Wyatt, & Peters, 2012). In order to achieve a normal, stable weight, energy expenditure must equal energy intake; when energy intake exceeds energy expenditure the result is an increase in body weight, most of which (60% - 80%) is body fat (J. O. Hill et al., 2012). The exact causes of the energy imbalance that underlies obesity are not fully characterized, however, evidence shows that appetite plays a crucial role. The first section of this review provides an overview of children's eating behavior followed by an overview of research relating to the effects of MSG on appetite.

Appetite Regulation in Children

Experimental studies have demonstrated that children have the capacity to self-regulate short-term energy intake by adjusting food intake in response to covert changes in energy content (Birch & Deysher, 1986; Johnson, 2000). Some research suggests that appetite is, in part, genetically determined. Various longitudinal and cross sectional studies have supported the idea that obesity and overweight runs in families by providing evidence that a major risk factor for overweight in children is having an overweight/obese parent (Gibson et al., 2007; Maffeis, Talamini, & Tato, 1998; Wang,

Patterson, & Hills, 2002; Whitaker, Wright, Pepe, Seidel, & Dietz, 1997). A study of 66 twin pairs aged 3- to 17- years found that BMI was 86% heritable and body fat was 76% heritable (Koeppen-Schomerus, Spinath, & Plomin, 2003). Similarly, a larger scale study of close to 2,000 sibling pairs, reported that genetic influences on BMI were 67%, 45%, and 81% for African American females, White females, and all males, respectively (Jacobson & Rowe, 1998). To assess appetite in the Twins' Early Development Study (Oliver & Plomin, 2007), parents of twins were asked to complete the Child Eating Behaviour Questionnaire (CEBQ) (Wardle, Guthrie, Sanderson, & Rapoport, 2001) which is designed to measure eating styles in young children. Results showed that satiety responsiveness was 63% heritable and food cue responsiveness was 75% heritable (Carnell, Haworth, Plomin, & Wardle, 2008). In a study of 100 obese and normal-weight children, children were exposed to four dinner conditions of varying portion size (100%, 150%, 200%, and 250% of the reference condition). Although total energy intake did not vary with weight status, appetitive traits were associated with increased energy intake. Children with lower satiety responsiveness and increased food responsiveness showed the greatest increases in intake across conditions (Mooreville et al., 2015). These studies provide evidence that obesogenic appetite traits are highly heritable and may relate to weight status.

At the same time, there is evidence that many social and situational aspects of children's eating environments may diminish the extent to which children attend to internal cues of hunger and satiety regulate eating (Birch & Fisher, 1997; Fisher & Birch, 2002; Mrdjenovic & Levitsky, 2005). For example, one study reported that consumption

of a main entrée was 29% greater when children were served a large portion compared to an age-appropriate portion, suggesting that portion size promotes excess energy intake (Fisher, Liu, Birch, & Rolls, 2007). Similarly, Fisher and colleagues (2003) not only found that doubling the portion size of an entrée, increased the children's energy intake by 25% but also that children consumed an additional 270 kcal in the absence of hunger from highly palatable energy-dense foods (Fisher, Rolls, & Birch, 2003). The manner in which parents interact with children around eating influences their appetite, regulation, and weight. Furthermore, higher levels of parental control in feeding have been associated with poorer appetite regulation (Johnson & Birch, 1994). A longitudinal study of girls by Birch and Fisher (2003) reported that "eating and the absence" (EAH) increased from 5 years to 9 years of age and that higher levels of maternal restriction at 5 years of age predicted higher EAH at 7 and 9 years of age (Birch, Fisher, & Davison, 2003). These results demonstrate children's self-regulation of appetite can be modified by situational and social cues.

Monosodium Glutamate- What is it and Why is it Used?

Glutamate is a naturally occurring amino acid found in many protein-containing foods, including vegetables, meats, and cheeses. Monosodium glutamate (MSG) is the sodium salt of the amino acid glutamate and is found in many common foods (e.g. salad dressings, savory snacks). Historically, MSG has been used as a flavor enhancer.

The addition of MSG to foods has been shown to increase acceptance of novel foods by increasing palatability because it imparts "umami," which is the Japanese word meaning "deliciousness" (Yeomans et al., 2008). Bellise et al, (1991) used a sample of

36 French men and women to test the effects of MSG on the palatability of new foods. Weekly tests of intake showed that after repeated weekly exposure of added MSG (0.6%), subjects ate a greater amount and at a faster pace compared to MSG- group, indicating that repeated exposure to MSG increased their desire to eat (Bellisle et al., 1991). In a similar study of 44 adults, repeated exposure to MSG increased the palatability of food. In the pre-test and post-test sessions, all participants tasted samples (10 ml) of three test soups without MSG and rated their liking and familiarity of each using a VAS. During the exposure sessions, both groups received two of the three soups, one with 0.5% added MSG and one without added MSG. Compared to pre-test, mean liking at post-test was significantly greater in both groups for all three soups, suggesting that repeated exposure to MSG increases the liking of it (Prescott, 2004).

Researchers have also investigated the potential effect of MSG to stimulate appetite among the institutionalized elderly, who commonly have impaired taste and smell perceptions, which has the potential to reduce dietary intake. One study investigated the effects of added MSG on common foods among a group of 50 elderly patients. A within-subject cross over design was used where MSG enhanced foods were served at meals for 4 week periods in one condition and without MSG enhancement in the other condition. Results showed that foods with added MSG significantly improved acceptability of those foods; increased acceptability was attributed to aroma and taste. Furthermore, participants consumed more MSG enhanced food than unenhanced food (Schiffman, 1998). A similar study, added 0.6% of MSG to target foods served in the cafeteria of a specialized house for the elderly. The addition of MSG increased intake of

some of the target foods and had a positive (increased calcium and magnesium intake) or negative (increased fat intake) nutritional effects (Bellisle et al., 1991). Both of these studies provide evidence that the addition of MSG, when provided in moderation, can increase palatability of foods and can provide nutritional benefits to the elderly who may have impaired senses to stimulate their food intake.

Effects of MSG on Appetite Among Adults

A more recent line of research indicates that MSG may increase satiety and suppress hunger, however, findings have been somewhat mixed. A study of 35 adults investigated the effects of a soup pre-load, differing in carbohydrate and protein content on appetite. Using a visual analogue scale, participants completed pre-test measures of appetite, then, after consuming their randomly assigned bowl of soup (450 g) they immediately rated their appetite; they continued rating their appetite every 15 minutes for 120 subsequent minutes. In the MSG+ with protein condition, there was a smaller decrease in hunger immediately after consumption of the soup, however over the subsequent 120 minutes, the increase in hunger was significantly lower compared to the MSG- with protein condition (Masic & Yeomans, 2013). In a similar study of 20- to 40-year old women, researchers tested the effects of four different pre-loads on appetite and subjective hunger. The four broths were 1) chicken base broth 2) chicken broth with MSG and nucleotides (MSG+), 3) chicken broth with MSG, and 4) chicken broth with added fat. Participants visited the laboratory for four consecutive weeks. Upon arrival, they completed appetite and hunger ratings and then consumed their first pre-load. After consumption, and for the following 15 minutes, they completed computer-based

questionnaires to measure hunger, fullness, desire to snack, desire to eat, and thirst. They then consumed their second pre-load, completed the same questionnaires, and then 45-minutes later, they consumed an *ad libitum* lunch. Results showed a significant reduction in hunger and desire to snack in the MSG+ condition compared to the base broth condition, however energy intake at the *ad libitum* lunch did not differ across MSG conditions (Carter et al., 2011). In a third adult study by Luscombe-Marsh (2009), participants completed 5 experimental sessions. Thirty minutes after consuming a first-course meal with varying MSG levels, participants were told they could eat whatever they wanted from a buffet containing 6 protein-rich and 6 carbohydrate-rich foods. Participants completed VAS ratings of hunger, fullness, and desire to eat before 10, 20, and 30 minutes after the first course meal. The addition of MSG to the high-protein first course meal did not influence perceived satiety and increased intake at the second course *ad libitum* meal compared to the high-protein meal without MSG (Luscombe-Marsh et al., 2009). In conclusion, 2 of 3 adult studies and 1 infant study provide evidence that MSG can: i) increase palatability, ii) either increase or decrease food intake at subsequent test meals in response to consumption of MSG, and iii) may enhance post prandial satiety.

Hypotheses

The overarching goal of this research was to experimentally evaluate the role of umami on appetite regulation among children. The primary aim was to determine the effects of adding MSG (MSG+) to a first course (pre-load) on energy intake at a subsequent test meal (objective satiety). Children who consumed the MSG+ pre-load

were expected to show increased satiety relative to a no-load condition and the magnitude of this difference was expected to be greater in children in the MSG+ condition.

A secondary aim was to determine the effects of the addition of MSG to the pre-load on perceived hunger and fullness at a meal. Children who consumed the MSG+ pre-load were expected to show increased self-reported fullness and decreased hunger relative to the no-load condition and relative to the children who consume the MSG- pre-load

CHAPTER 3

MATERIALS AND METHODS

Study Design

A between-subjects design with a within-subjects condition was used to evaluate the effect of monosodium glutamate (MSG) on perceived and objective satiety. The MSG content (MSG+ vs. MSG-) of a first course pre-load soup was systematically increased to create two conditions; children were randomly assigned to experimental condition. Each child was seen in a no-load condition, which served to provide an additional comparison to the experimental conditions by assessing children's food intake at the *ad libitum* meal in the absence of a pre-load. The order of the pre-load and no-load conditions was counterbalanced. Fixed portions of an entrée (macaroni and cheese), two vegetables (corn and peas) and water were served at each meal and did not vary across conditions. Perceived hunger and fullness were evaluated using a visual analogue scale (VAS), issued before and after consumption of the pre-load (Stubbs et al., 2000). Objective satiety was assessed based on total energy intake at the *ad libitum* meal measured using weighed food intake methods. Demographic information was obtained by caregiver self-report.

Participants

Participants were healthy children, aged 7-9 years, and a their primary caregiver (≥ 18 years). Parent-child dyads were excluded if the child reported a dislike of two or more of the foods on the menu (screened based on caregiver report) as well as any chronic medical conditions (e.g. diabetes, cystic fibrosis), severe food allergies (e.g.,

gluten, peanuts), special diets (e.g., weight management programs, nutrition counseling), or developmental issues (e.g., Autism) known to affect food intake or growth. Due to anecdotal reports of glutamate sensitivity among children with severe asthma (Williams & Woessner, 2009), children with asthma were also excluded from the study.

Convenience sampling was used where participants were recruited through advertisements, which included a phone number that potential study participants could call to be screened, in a popular newspaper in the Philadelphia region. Families were compensated for their participation with a \$50 Visa gift card for each of 3 visits, for a total for \$150. All study procedures were reviewed by and conducted in accordance with standards set forth by the Temple University Institutional Review Board.

Experimental Menu

As shown in Table 1, the MSG pre-load was a 150 g serving of chicken broth with star-shaped pasta noodles. The stock base [*Whole Foods 365 Organic Chicken Broth*] was selected to have a very low glutamic acid concentration (0.01% weight/weight). In the MSG+ pre-load condition, 0.75 g of MSG [*Ajinomoto, Inc*] was added to 150 g of the stock base. The MSG content of the MSG+ pre-load fell in the range of glutamate typically found in foods in the United States (0.1-0.008% weight/weight) and is consistent with other MSG pre-loading studies (0.5 g MSG / 100 g broth) (Carter et al., 2011; Luscombe-Marsh et al., 2009; Yeomans et al., 2008). Sodium content was matched across MSG- and MSG+ soups by the addition of 0.3972 g /150 g serving of iodized salt to the MSG- base. The soups were prepared in batches of six

servings and heated to 71.1°C in crockpots. A small amount (15 g) of cooked pasta (*Pasta Mia Stelline*) was added to all soup pre-loads immediately before serving.

| Table 1 Pre-load ingredients (per serving) | | |
|---|----------|----------|
| | MSG+ (g) | MSG- (g) |
| Whole Foods 365 Organic Chicken Broth | 150 | 150 |
| Morton Iodized Salt | - | 0.3972 |
| Ajinomoto Monosodium Glutamate | 0.75 | - |
| Pasta Mia Stelline (cooked) | 15 | 15 |

The *ad libitum* meal consisted of pasta (Kraft Macaroni and Cheese; 2.02 kcal/g, 366.3g), corn (Green Giant Niblets Corn & Butter Sauce; 0.73 kcal/g, 85g), peas (Green Giant Sweet Peas & Butter Sauce; 0.71 kcal/g, 85g), and water (Poland Spring; 0 kcal/g, 279.0g). The meal provided a total of 861 kcal which is 46% of the estimated energy requirement for children aged 6-11 y (Otten, Hellwig, & Meyers, 2006). The orientation of foods to one another (e.g. the entrée was always plated on the left side of the plate) was held constant across conditions.

Procedures

Data collection occurred between April 2014 and May 2015. Recruitment was rolling where 4-8 families were seen in 3-week cycles. Caregivers were instructed to refrain from giving their children anything to eat or drink for 2 hours prior to each visit. An introductory visit was included to familiarize the children with the laboratory setting, staff, and meal procedures as well as to obtain the following: informed consent from parents for their own and their child's participation as well as child assent; caregiver self-report questionnaires (demographics, Children's Eating Behaviour Questionnaire, and

Caregiver's Feeding Styles Questionnaire); ratings of child food preferences for the experimental menu; and measured height/weight from children.

Children were seen in at each experimental condition at a dinner meal. As shown in Figure 1, in the pre-load condition, children completed a visual analogue scale (VAS) for perceived hunger and fullness. Participants then consumed their randomly assigned soup pre-load (MSG+ or MSG-). Immediately following consumption of the pre-load, each child completed the second set of VAS ratings. Consistent with previous pre-loading studies, a 30-minute delay was used between the pre-load consumption and the *ad libitum* meal (Luscombe-Marsh et al., 2009; Rogers & Blundell, 1990). Following the 30-minute delay, children consumed the *ad libitum* meal. In the no-load condition, children completed the VAS ratings at the same time intervals as in the pre-load condition and were then provided the *ad libitum* meal. Child consumed the 20-minute *ad libitum* meal with 2-3 other children and a trained staff member apart from their parents, with the instructions to eat as little or as much as desired. The staff member ensured that procedures were followed and that food-related conversation was minimized. Caregivers completed questionnaires in a waiting room located in the laboratory while their children ate dinner.

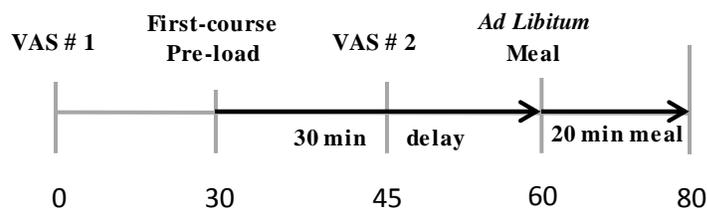


Figure 1 Protocol for pre-load and no-load sessions

Figure 1 describes the time intervals of the experimental sessions. As soon as participants arrived, they completed the first set of appetite ratings using a Visual Analogue Scale (VAS). Next, they consumed their randomly assigned pre-load soup. Following that was a 30-minute delay; during this time they completed their second set of appetite ratings. Finally, they consumed the 20-minute *ad libitum* meal in which they could eat as little or as much as they wanted. In the no-load condition, the protocol was exactly the same with the absence of the first-course pre-load.

Measures

Perceived Satiety

Children's perceptions of hunger and fullness were assessed using 100 mm visual-analogue scales anchored by 'Not at All' and 'Extremely' (Stubbs et al., 2000). Ratings were completed immediately before and after consuming the soup pre-loads. Children also completed VAS ratings in the no-load condition at the same time interval. VASs are commonly used and have been proven to be valid measures of subjective ratings of appetite mood, and pain (Bekem et al., 2004; Chambliss, Heggen, Copelan, & Pettignano, 2002; Flint, Raben, Blundell, & Astrup, 2000). Further, VASs have been successfully administered to children to assess perceptions of appetite and have been found to be as reliable as Likert scales in children aged ≥ 6 years (Laerhoven, Zaag-Loonen, & Derkx, 2004). A study conducted by Anderson et al. (1989) concluded that VAS were appropriate measures for children because self-reported measures of hunger

and satiety fluctuated with time (e.g. meals decreased ratings of hunger and increased ratings fullness) (Anderson, Saravis, Schacher, Zlotkin, & Leiter, 1989).

Objective Satiety

Weighed methods were used to measure children's food intake to the nearest 0.1 g in each condition. Manufacturers' information was used in conjunction with food intake data to estimate energy intake (kcal) in each condition. Objective satiety was assessed as total energy intake at the meal.

Weight Status

Height and weight measurements were obtained in light clothing, without shoes, using procedures described by Lohman et al. (Lohman, Roche, & Martorell, 1988). A digital scale (Detecto, model 758C, Webb City, MO) was used to obtain duplicate weight measurements to the nearest 0.1 kg and wall-mounted stadiometer (Holtain Limited, Harpenden, Pems, UK) was used to obtain duplicate height measurements to the nearest 0.1 cm. A third measurement was taken and the discrepant measure discarded in cases where the weight measurements varied by >0.1 kg or height measurements varied by >0.1 cm. BMI-for-age percentiles and z-scores were calculated using CDC reference data (Kuczmarski & Flegal, 2000).

Demographic Data

Caregiver's report of basic demographic information included child/caregiver race/ethnicity, caregiver level of education, employment status and marital status, and participation in federal low-income programs (e.g. Head Start, WIC).

Food Preference

Children's liking of foods on the standard menu was verified using a tasting procedure (Birch, 1979). Children were interviewed individually, asked to taste each food, and categorize their liking using a 5-point scale with cartoon drawings depicting "Super Yummy," "Yummy," "Ok," "Yucky," and "Super Yucky" (Carraway-Stage, Spangler, Borges, & Goodell, 2014). 57.8% of the participants rated all 3 foods as "Yummy" or "Super Yummy". 13.7% of the participants rated one or more of the foods as "Super Yucky".

Statistical Analyses

Statistical analyses were performed using Stata/Se (Version 14, College Station, TX). Descriptive statistics were generated for the child's gender, race, weight status (BMI-for-age percentile <85th percentile, BMI-for-age percentile \geq 85th percentile), liking of test foods, caregiver gender, race, level of education, employment status, and participation in federal low-income programs. Means and standard deviations were calculated for child age and caregiver age and BMI. ANOVA was used to evaluate the effects of the MSG-enhanced pre-load on the outcomes of interest, with and without the inclusion of selected covariates.

Difference scores were generated for perceived hunger and fullness (pre-load post fullness rating – pre-load pre fullness rating; pre-load post hunger rating – pre-load post hunger rating). The association between MSG condition and perceived hunger difference score was tested using ANOVA. This model was repeated using perceived fullness difference score as the outcome variable. Potential confounding factors included child

gender and weight status, average liking of test foods, no-load average hunger rating, and pre-load average hunger rating. Covariates remained the same in all of the perceived satiety (hunger and fullness) models.

For objective satiety, a difference score was generated (pre-load kilocalories – no-load kilocalories) to investigate if MSG condition had an effect on the amount the children were eating at the pre-load *ad libitum* meal compared to the no-load *ad libitum* meal. MSG condition was used as a predictor of energy intake (difference score of kilocalories) using ANOVA. Potential confounding factors included in the model were child gender and weight status, average liking of the foods served at the *ad libitum* meal, average perceived hunger rating (no-load condition) and average fullness rating (no-load condition). For all analysis, a *p*-value of <0.05 was used to infer statistical significance.

CHAPTER 4

RESULTS

Participants were 102 healthy children (55% female) and their primary caregiver (Table 2). On average, children were 8.0 ± 0.8 years old and a majority were African Americans (78.4%). Close to a third of children were overweight or obese. Caregivers (93% female) had a mean age of 40.0 ± 8.5 years. Most caregivers had more than (74.5%) a high school education and (77.5%) reported participation in federal low-income programs (e.g. SNAP, Head Start).

| Table 2 Baseline demographic variables | |
|---|------------------|
| Caregiver (unadjusted mean \pm SD or n (%)) ($N=102$) | |
| <i>n</i> | 102 |
| Age, y | 40 ± 8.5 |
| Sex, % female | 95 (93.14%) |
| Race, % AA | 85 (83.33%) |
| Body mass index (BMI) | 29.3 ± 6.8 |
| Education, % | |
| \leq HS | 26 (25.49%) |
| Some college | 41 (40.20%) |
| \geq College | 35 (34.31%) |
| Employment, % | |
| Employed | 40 (39.22%) |
| Unemployed | 62 (60.78%) |
| Participation in federal low-income programs, % | 79 (77.45%) |
| Child (unadjusted mean \pm SD or n (%)) ($N=102$) | |
| <i>n</i> | 102 |
| Age, y | $8 \pm .81$ |
| Sex, % female | 57 (55.0%) |
| Race, % AA | 80 (78.43%) |
| BMI-for-age percentile | 63.78 ± 29.9 |
| Weight status, % | |
| Healthy weight | 70 (68.63%) |
| Overweight/obese | 32 (31.38%) |

Perceived Hunger and Fullness

As shown in Figure 2, there was a main effect of MSG condition on changes in perceived hunger following the consumption of the pre-load. Children in the MSG+ condition showed greater decreases in perceived hunger following the consumption of the pre-load than children in the MSG-condition (MSG+: pre pre-load 70.3 ± 3.2 post pre-load 51.1 ± 3.2 ; MSG- pre pre-load 63.4 ± 3.5 post pre-load 57.9 ± 3.5 ; $F(1, 101)=4.05$, $p<0.05$).

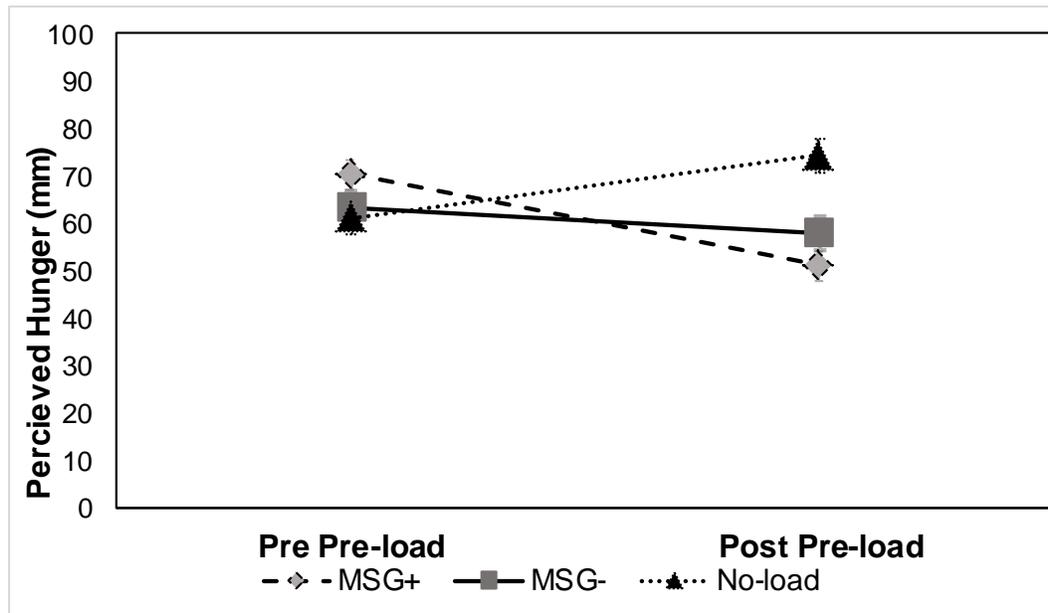


Figure 2 Effect of monosodium glutamate (MSG) on perceived hunger. Analysis of variance was used to estimate effects of MSG on children's perception of hunger, prior to and immediately following, consumption of a pre-load that either contained added MSG (MSG+) or no MSG (MSG-). A main effect of MSG on changes in perceived hunger following the consumption of the pre-load was observed. Children in the MSG+ condition showed greater decreases in perceived hunger following the consumption of the pre-load than children in the MSG-condition ($p<0.05$). Data are shown as adjusted mean \pm SEM.

As shown in Figure 3, perceived fullness increased following consumption of the pre-load. However, changes in perceived fullness following the pre-load did not differ between MSG conditions ($F=0.08$, $p=0.78$).

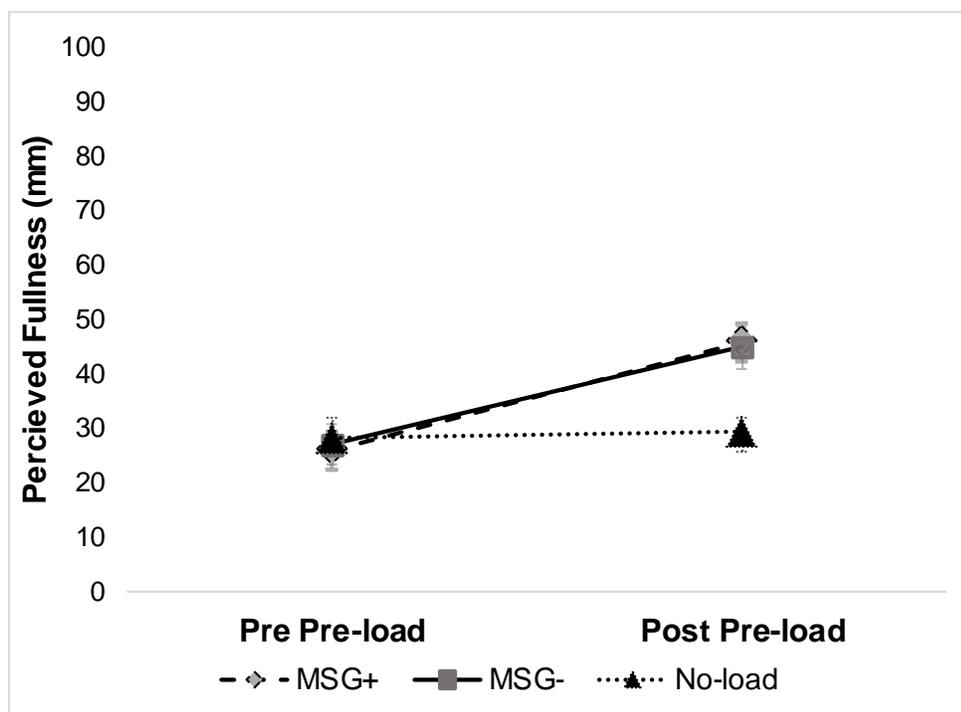


Figure 3 Effect of monosodium glutamate (MSG) on perceived fullness. Analysis of variance was used to estimate effects of MSG on children's perception of fullness, prior to and immediately following, consumption of a pre-load that either contained added MSG (MSG+) or no MSG (MSG-). Perceived fullness increased following consumption of the pre-load. However, changes in perceived fullness following the pre-load did not differ across MSG conditions ($p=0.78$). Data are shown as adjusted mean \pm SEM.

Objective Satiety

All children included in the analysis ($n=102$) consumed the soup pre-load in full which contained 150 grams of broth and 15 grams of cooked pasta for a total of 26.2 kilocalories. As shown in Figure 4, MSG did not influence objective satiety. Total

energy intake at the *ad libitum* meal did not vary by condition. Total energy intake at the *ad libitum* meal was 532.6 ± 219.57 kcal in the pre-load and 539.9 ± 230.82 kcal in the no-load condition. Similar numbers of children ate less/more in the pre-load condition compared to the no-load condition (60% of children ate more and 40% of children ate less).

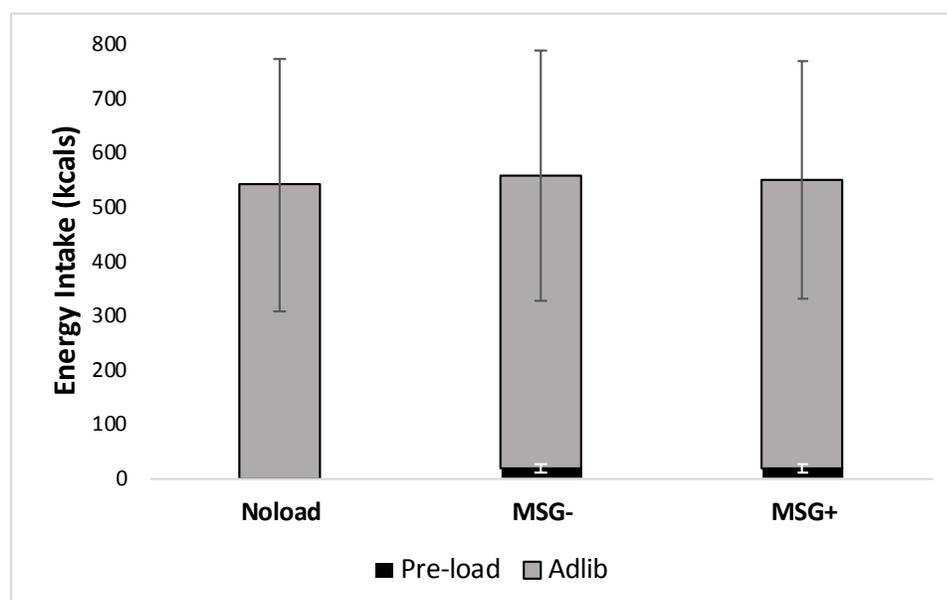


Figure 4 Effect of monosodium glutamate (MSG) on objective satiety. Analysis of variance was used to estimate effects of MSG on children's objective satiety. Total energy intake at the *ad libitum* meal was 536.6 ± 219.57 kcal in the pre-load condition and 539.9 ± 230.82 kcal in the no-load condition. Data are shown as mean \pm SD.

CHAPTER 5

DISCUSSION

To our knowledge, this is the first study specifically designed to evaluate the effects of monosodium glutamate on perceived and objective satiety among children. Results showed that children who consumed the MSG+ pre-load showed a greater decrease in perceived hunger after consuming the soup in the MSG+ condition than those children in the MSG- condition. However, no effects were seen on objective satiety. These findings suggest that MSG may have suppressive effects on children's perceived hunger, but these may not clearly translate to eating behavior.

Effects of MSG on perceived satiety are consistent with those of two adult studies. Similar to the current study, Carter et al. (2011) asked participants to rate their appetite using a VAS at various time intervals throughout the session and found that MSG had a suppressing effect on hunger (Carter et al., 2011). An additional study reported similar findings; immediately following consumption of MSG+ pre-load, participants reported a small decrease in hunger using VAS compared to those who consumed the MSG- pre-load (Masic & Yeomans, 2013). In addition to the current study, these studies support the notion that MSG has the potential to decrease subjective ratings of perceived hunger. In contrast, in a study of adults, hunger and fullness ratings were not different across MSG conditions (Luscombe-Marsh et al., 2009).

In this study, consumption of the MSG pre-load did not influence objective satiety measured by total energy intake at an *ad libitum* meal. The absence of an effect of MSG on observed satiety is consistent with findings of two adult studies. In a sample of 20- to

40- year old women, desire to snack and hunger decreased in the MSG+ condition compared to the base broth condition and the addition of MSG did not alter intake at the test meal (Carter et al., 2011). A similar study conducted by Rogers & Blundell (1990), reported that the those who consumed the MSG+ soup had reduced appetitive ratings and increased fullness rating, however food intake at the test meal was not significantly different across conditions (Rogers & Blundell, 1990). However, the results of the present study differ from several adult studies and one study of infants that have objective appetite suppressive effects of MSG on satiety (Masic & Yeomans, 2014; Ventura et al., 2012).

It is unclear why effects of MSG to reduce perceived hunger did not result in reduced intake at the test meal. Although the concentration of MSG was exactly that of previous studies (Carter et al., 2011; Yeomans et al., 2008), it is possible that the total energy provided in the pre-load (17.5 kcal/100g) was insufficient to produce effects. Other pre-loading studies conducted in adults have used preloads ranging from 10.0-69.9 kcal/100g (Birch & Deysher, 1986; Birch, McPhee, Shoba, Steinberg, & Krehbiel, 1987; Cecil et al., 2005; Kral et al., 2012). For example, in a study by Kral et al (2012), children in the younger age group (5-8 years) were served 100 g of pudding varying from 57.0 – 97.0 kcal (Kral et al., 2012). Another possibility is that reductions in perceived hunger may have influenced dimensions of satiety not measured in this study, such as the inter-meal interval. In a study of infants, the test meal was provided when the participant signaled hunger (e.g. fussiness, biting on their hand), which was on average 3 hours following the first formula meal. The inter-meal interval did not vary by formula

condition (Ventura et al., 2012). In the present study, the inter-meal interval was fixed; children were provided an *ad libitum* meal 30 minutes following consumption of the pre-load. Whether MSG influences inter-meal interval among children requires additional research.

A number of limitations qualify the results of the study. First, although an introductory visit was used to familiarize children with the lab setting and procedures it is possible that the measurements did not accurately depict children's typical eating behavior. Whether the children would have eaten more or less at the *ad libitum* meal in their typical eating environment is unknown. Further, while a trained staff member was in the room to ensure protocol was being followed, it is possible that the influence of other children's behavior affected how much a child ate. For example, if a child noticed that the person he/she was sitting next to was not eating a lot of the food, he/she may have reduced how much food he/she consumed as well. Due to the nature of the design, this study did not provide the experience for children to learn the sensory dimensions associated with post-ingestive effects therefore, it is unclear if MSG-enhanced foods have the potential to influence appetite in children through sensory cues associated with proteins. A majority of the children that participated were non-Hispanic African American, so the findings may not be generalizable to children of other ethnicities. Further, given that non-probability convenience sampling was used to recruit participants, the sample may not be representative to the entire population.

In conclusion, the findings of this research indicate that MSG-enhanced foods may have suppressive effect on perceived hunger among children, but not objective

satiety. These findings indicate that while MSG acts to enhance flavor in foods, it does not appear to stimulate food intake in children. Rather, foods containing added MSG may actually promote healthy appetites in children by reducing hunger. Additional research is needed to consider effects of MSG on other aspects of appetite, including studies evaluating effects on inter-meal intervals and studies of satiation that manipulate the MSG content of foods eaten within meals or snacks.

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APPENDIX B

PRACTICE RUNS TRAINING

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM) COURSEWORK REQUIREMENTS REPORT*

* NOTE: Scores on this Requirements Report reflect quiz completions at the time all requirements for the course were met. See list below for details. See separate Transcript Report for more recent quiz scores, including those on optional (supplemental) course elements.

- **Name:** Alexandria Orloski (ID: 3021923)
- **Email:** amo@temple.edu
- **Institution Affiliation:** Temple University (ID: 926)
- **Institution Unit:** Public Health
- **Phone:** 570-592-5060

- **Curriculum Group:** Human Research
- **Course Learner Group:** Practice Runs Training
- **Stage:** Stage 1 - Basic Course

- **Report ID:** 14452161
- **Completion Date:** 02/03/2015
- **Expiration Date:** 02/03/2016
- **Minimum Passing:** 100
- **Reported Score*:** 100

| REQUIRED AND ELECTIVE MODULES ONLY | DATE COMPLETED | SCORE |
|------------------------------------|----------------|------------|
| Practice Runs Training | 02/03/15 | 2/2 (100%) |

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

CITI Program
 Email: citisupport@miami.edu
 Phone: 305-243-7970
 Web: <https://www.citiprogram.org>

Collaborative Institutional
 Training Initiative
 at the University of Miami

APPENDIX C

SOCIAL/BEHAVIORAL RESEARCH COURSE

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI)

HUMAN RESEARCH CURRICULUM COMPLETION REPORT

Printed on 01/29/2014

| | |
|------------------------|--|
| LEARNER | Alexandria Orloski (ID: 3021923) 3223 N Broad Street Philadelphia PA 19147 United States |
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| EXPIRATION DATE | 08/21/2015 |

SOCIAL/BEHAVIORAL RESEARCH COURSE : Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in Social/Behavioral Research with human subjects.

| | |
|----------------------|----------------|
| COURSE/STAGE: | Basic Course/1 |
| PASSED ON: | 08/21/2013 |
| REFERENCE ID: | 11039038 |

| REQUIRED MODULES | DATE COMPLETED | SCORE |
|---|----------------|------------|
| Belmont Report and CITI Course Introduction | 08/29/12 | 3/3 (100%) |
| Students in Research | 01/22/13 | 8/10 (80%) |
| History and Ethical Principles - SBE | 08/21/13 | 4/5 (80%) |
| Defining Research with Human Subjects - SBE | 08/21/13 | 4/5 (80%) |
| The Regulations - SBE | 08/21/13 | 4/5 (80%) |
| Assessing Risk - SBE | 08/21/13 | 5/5 (100%) |
| Informed Consent - SBE | 08/21/13 | 5/5 (100%) |
| Privacy and Confidentiality - SBE | 08/21/13 | 5/5 (100%) |
| Research with Prisoners - SBE | 08/21/13 | 3/4 (75%) |
| Research with Children - SBE | 08/21/13 | 4/4 (100%) |
| Research in Public Elementary and Secondary Schools - SBE | 08/21/13 | 4/4 (100%) |
| International Research - SBE | 08/21/13 | 3/3 (100%) |
| Internet Research - SBE | 08/21/13 | 5/5 (100%) |
| Research and HIPAA Privacy Protections | 08/21/13 | 5/5 (100%) |
| Vulnerable Subjects - Research Involving Workers/Employees | 08/29/12 | 4/4 (100%) |
| Conflicts of Interest in Research Involving Human Subjects | 08/29/12 | 5/5 (100%) |
| Unanticipated Problems and Reporting Requirements in Social and Behavioral Research | 08/21/13 | 2/3 (67%) |
| Temple University | 08/29/12 | No Quiz |

For this Completion Report to be valid, the learner listed above must be affiliated with a CITI Program participating institution or be a paid Independent Learner. Falsified information and unauthorized use of the CITI Program course site is unethical, and may be considered research misconduct by your institution.