Running Head: Food Portion Size Area and Expected Anxiety

Title: Food Portion Size Area Mediates Energy Effects on Expected Anxiety in Anorexia Nervosa

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Highlights

- Anxiety increased more per kcal with low rather than high energy-dense foods.
- Visual inspection suggested food area was driving anxiety responses.
- Imaging software was used to measure physical area for images of food portions.
- Anxiety regressed from area was greater for high energy-dense foods.
- Area mediated the relationship between energy and the anxiety response.

Abstract

A study in which adolescent patients with anorexia nervosa (n = 24) rated their expected food-anxiety in response to images of portions of food (potatoes, rice pizza, and M&Ms) showed that lower energy-dense foods elicited higher expected anxiety per kilocalorie than higher energy-dense foods. However, the area of the portion sizes could be an unmeasured variable driving the anxiety response. To test the hypothesis that area mediates the effects of energy content on expected anxiety, the same images of portions were measured in area (cm^2), and standardized values of expected anxiety were regressed from standardized values of energy and area of portions. With regression of expected anxiety from portion size in area, M&Ms, which had the highest energy density of the four foods, elicited the highest expected anxiety slope (β = 1.75), which was significantly different from the expected anxiety slopes of the other three foods (β range = .67 - .96). Area was confirmed as a mediator of energy effects from loss of significance of the slopes when area was added to the regression of expected anxiety from energy x food. When expected anxiety was regressed from food, area, energy and area by energy interaction, area accounted for 5.7 times more variance than energy, and β for area (0.7) was significantly larger (by 0.52, SE = 0.15, t = 3.4, p= 0.0007) than β for energy (0.19). Area could be a learned cue for the energy content of food portions, and thus, for weight gain potential, which triggers anxiety in patients with anorexia nervosa.

Key Words: Eating disorders, Anorexia nervosa, Portion size, Anxiety, Food choice, Energy density

1 INTRODUCTION

Severely reduced caloric intake is a hallmark of anorexia nervosa (Sysko, Walsh, Schebendach, & Wilson, 2005). Research has shown that food-related anxiety and obsessionality are important contributors to intake restricting behaviors (Wilson, Touyz, O'Connor, & Beumont, 2013, Gianini, et al., 2015). Steinglass and colleagues (2010) demonstrated that pre-meal anxiety was significantly and negatively correlated with intake of both a multi-item and a single-item meal (macaroni and cheese); such that patients' intakes were significantly lower than those of healthy controls. Patients with anorexia nervosa (AN) also tend to be preoccupied with the calorie content and portion size of foods because of fear of weight gain (Halmi, 2007). Although a relationship between fear of food and food intake has been proposed (Steinglass, et al., 2011), few studies have systematically assessed the predictors of food-related anxiety in anorexia. Accurate cooperation and compliance with assessments and treatment is also a common problem with patients with AN (Crisp & Kalucy, 1974), because they fear loss of control over eating and of weight-gain (Vitousek, Watson, & Wilson, 1998).

To compare differences in the anxiety potentials of foods, Kissileff, Brunstrom, Tesser, Bellace, Berthod, Thornton, and Halmi (2016) used a novel paradigm to measure expected anxiety responses to food. To avoid causing distress to the participants, a computerized task with images of foods, rather than actual food portions, was used. Four pictured foods were tested: M&Ms® and pizza, to represent tasty high energy-dense foods, and plain rice and potatoes to represent bland low energy-dense foods. These foods are also common components of the American diet (Smiciklas-Wright, Mitchell, Mickle, Cook, & Goldman, 2002).

Insert Table 1 here

In that preliminary study, Kissileff, et al. (2016) proposed that increases in the energy of a portion would produce measureable increases in expected anxiety, and that higher energy-dense foods would produce more expected anxiety than low-energy dense foods. Participants' anxiety responses were regressed from the calorie content of portions, and the expected anxiety-inducing potential of a food was derived from the slope of the response level as the portion size increased. Paradoxically, in patients with AN, steeper expected anxiety slopes (that is, more anxiety per log kilocalorie) were found for the foods with a lower energy density (rice and potatoes) than for the foods higher in energy density (pizza & M&Ms). This result was not explained by the participants' liking of the foods or by their familiarity ratings. The result of greater fear of low-energy dense foods contradicts evidence that patients with AN tend to avoid high energy-dense foods to prevent weight gain (Jiang, Soussignan, Rigaud, & Schaal, 2010). Visual examination of the food images suggested that the physical size of the portions and not their energy content was the common factor that predicted anxiety responses. For example, (Figure 1), portions of pizza (320 kilocalories) and rice (160 kilocalories) that differed in energy content, occupied equivalent areas on the plate and both elicited identical anxiety responses on a VAS anxiety scale (see Kissileff, et al., 2016). Several other pairings can be observed by comparison of food energies and areas in Table 1 and Figure 1. To determine whether these observations were mere illusions or actual contributors to the response, in the current report, areas of the food images were measured and the original data were re-analyzed, so that contributions of both area and energy could be assessed independently and in combination.

Insert Fig. 1 here

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2. MATERIALS AND METHODS

2. 1 Study Sample

Data were reanalyzed from twenty-three females and one male, all of whom met the DSM-IV criteria for anorexia nervosa, as determined by a licensed psychiatrist, using the Structured Clinical Interview (First, Gibbon, Spitzer, & Williams, 1996). The DSM-IV was the most current version of the DSM in use at the time of data collection. Participants were recruited from the Weill Cornell Medical College treatment facility in White Plains, NY, between October 2008 and June 2010. The Yale-Brown-Cornell Eating Disorder Scale (Mazure, Halmi, Sunday, Romano, & Einhorn, 1994) was used to measure the severity of their eating disorder symptomatology. Participants demographic characteristics (mean ± SD) by group (anorexic restrictive type [N = 21], anorectic binge-purge type [N

= 3]) were as follows: Age in years (15.62 ± 1.56, 14.33 ± 1.15), body mass index in kg/m^2 (17.09 ± 1.39, 17.23 ± 1.03), target weight in lb (119.2 ± 12.35, 104.67 ± 4.16), Current weight in lb (100.32 ± 12.50, 93.43 ± 8.14), YBC-EDS score (11.00 ± 7.31, 8.67 ± 7.64) Data from the two groups were combined for analysis, because their body mass index and eating disorder scores did not differ significantly. Severity of illness, measured by YBC-EDS scores, was low in these outpatient participants. Thus, results are generalizable only to a moderately ill population of adolescents with anorexia nervosa.

2.2 Data Collection and Processing Procedures

To account for variability in time elapsed since the last meal; participants were fasted at least two hours before the study task and provided ratings of their hunger and the time of their last meal (Kissileff, et al., 2016). Hunger ratings did not have an effect on responses for any of the foods when added to the model, and are therefore not included in this analysis. To determine expected anxiety from foods, images of the four foods noted above (potatoes, rice, pizza and M&Ms) were presented on a 19-inch square monitor in a counterbalanced order. Across trials, they were all presented randomly in five different portion sizes; 20, 40, 80, 160, and 320 kilocalories. Participants were asked to respond to the question "How stressful would it be for you to consume this food?" and to mark a visual-analogue scale anchored with "No anxiety at all," and "This would give me a panic attack." Participants were also asked to rate how much they liked the foods, how familiar the foods were, how frequently they ate the foods, and how healthy they thought the foods were (Herzog, Douglas, Kissileff, Brunstrom, & Halmi, 2016).

Although only four foods, two from each category (high and low energy-dense), where used in this task, to prevent participant fatigue, future studies should be conducted with a more varied range of foods to determine whether energy-density or other dimensions are critical to food-anxiety.

In the previous report (Kissileff, et al., 2016), when expected anxiety was regressed from portion size in kilocalories, potatoes induced the most expected anxiety per kilocalorie (55.92 ± 3.76, P <0.0001), followed by rice (51.24 ± 3.76, P <0.0001), then pizza (30.96 ± 3.76, P <0.0001), and finally M&Ms (27.41 ± 3.76, P <0.0001). To test a new hypothesis that the area of a portion size drives the anxiety response to foods in patients with anorexia nervosa, photo-imaging software was used to measure the two-dimensional area of the food in the images presented in each trial. This technique has been found to deliver accurate and reproducible results (Kurien, Ganpule, Muthu, Sabnis, & Desai, 2009). Outlines of the food portions were traced with a cursor in Adobe Photoshop®, and the program computed the pixel count for the portion of the image within the outline. Pixels are the smallest units of information in an image and their number determines the size of the image. To convert the pixel values of the captured portions to cm^2, the ratio of area of the entire photo in centimeters to number of pixels in the photo was computed, and its value was 0.002081448 cm^2/pixel. The area of each portion was computed by multiplication of the number of pixels in each portion by this pixel constant (see Table 2 for kilocalories and area values of portions).

Insert Table 2 here

2.3 Statistical Analysis

PROC GLM with effect size and solution options in SAS 9.4 was used to generate separate regressions of expected anxiety scores for each subject, food, and portion size, quantified both by energy content and by area (n = 480, 24 subjects x 4 foods x 5 portion sizes x 2 measurement units). Expected anxiety responses and portion size in area and energy were standardized to their respective means to eliminate the effect of non-comparable units. The effects of energy, area, and food type were determined by comparison of regression models of expected anxiety from area and energy alone and combined with the interactions of kilocalories and area by food. Statistical significance of the slopes (partial correlations) was compared among four regression models. For model 1 expected anxiety response was regressed from energy by food, to determine the effect of energy alone for each food. For model 2 expected anxiety was regressed from the area by food interaction to determine the direct effect of area on anxiety responses from each food. For model 3, expected anxiety response was regressed from food by area with the addition of kcal as a mediator, and for model 4, expected anxiety response was regressed from the food by kcal interaction with area as a mediator. Models 3 and 4 were used to determine the directionality of the mediation, i.e. whether area mediated energy or the converse. Food as a main effect was included in each model to generate intercepts for the regression of expected anxiety responses from each food. The analyses are in accordance with the Baron and Kenny model (Baron & Kenny, 1986), in which a mediation effect is determined by comparison of the results of three paths; that of the direct effect of the independent variable on the outcome, the effect of the mediator variable on the outcome, and the additive effect of the independent and mediator variables on the outcome. In the Baron and Kenny method, a variable is considered to mediate the effect of the independent variable on the outcome to the extent that its presence in the regression model diminishes the previously significant effect of the independent variable on the outcome. Although Baron and Kenny use only main effects in their model, this method still applies to interaction effects. Planned contrasts were used to test for significant differences between foods in the amount of expected anxiety produced as portion sizes increased.

Finally, an ANOVA was used to test the contributions of each variable, independent of portion size, on expected anxiety (EA) responses. Type III sums of squares for main effects are reported, as results of Type III sums of squares exclude shared variance between the variables and are invariant to the ordering of the effects in the model. Models were run with the subject ID included to reduce the error variance associated with differences among subjects. An alpha of .05 was applied to all statistical tests reported as significant.

3. RESULTS

3.1 Model Comparisons

For model 1 (EA = food + food*kcal), there was a significant ($F_{4,449}$ = 190.03 $p < .0001$) food x energy interaction (i.e. slope) on expected anxiety, and this interaction was significant for each food. The results for all models are summarized in Table 2. Potatoes generated the steepest EA slope (ß= 0.86, SE= 0.05, t = 17.46, $p < .0001$), as previously reported for unstandardized values (Kissileff, et al, 2016). The slopes of the low energy dense foods, potatoes and rice, were not different from one another but both were significantly greater than the slopes of the high energy-dense foods, pizza and M&Ms (see Figure 2).

When anxiety responses were regressed from area (Model 2, EA = food + food*area), the pattern of results was reversed from that seen in Model 1 (see Figure 3 for graphic depiction of slopes). In Model 2, the highest slope of EA from area was from M&Ms, which was significantly steeper than the slopes for rice, potatoes, and pizza.

Insert Fig. 2 and 3 here

The addition of kcal to the Model 2 (i.e. Model 3, EA = food + food*area + kcal) increased the steepness of the slopes. The significance of the slopes of pizza and M&Ms was lowered from <0.001 to <0.01 and <0.05, respectively, and this result indicates that the energy effect may be partially mediated by the effect of area for those foods. The overall model was significant and differences between rice and potatoes and between M&Ms and the three other foods remained significant.

Model 4 (EA = food + food*kcal + area) added the area variable to Model 1. The overall model remained significant, but all the slopes were rendered non-significant, except for M&Ms ($p < 0.05$). The change in significance level indicates that the energy effect was mediated by area for potatoes, pizza, and rice, and partially for M&Ms. Differences between individual slopes for each food were also non-significant, except for the differences between rice and potatoes ($p < .01$),

Insert Table 2 here

3.2 ANOVA for Effects of Participant, Food, Area, Energy and Area by Energy Interaction

Sources that explained the most variance in EA responses were participant effects, followed by food. Area accounted for more variance in the expected anxiety responses than did energy content of portions (see Table 3).

Insert Table 3 here

4 SUMMARY

4. 1 Discussion of Findings

Both direct and indirect effects of area on anxiety response were demonstrated by a mediation analysis with energy and area, and area of portions accounted for more of variance than did energy, on expected anxiety response across portion sizes between foods. Measurement of portions in units of energy content (Kissileff, et al., 2016) obscured the effect of visual cues on the anxiety response and resulted, paradoxically, in higher anxiety slopes for lower energy-dense foods. However, in the present report, when measurement of energy was substituted with portion size in units of area in the regression model of anxiety response from portion size, the pattern of energy-driven anxiety was reversed from the original result, and the highest anxiety between the foods was seen for M&Ms. The larger effect for area compared to energy content on anxiety responses suggests that patients with anorexia nervosa may make inferences about the weight-promoting potential of foods by their using the physical size of a portion, as a cue for its energy content.

Learning of portion size energy from area cues could be analogous to flavor nutrient learning, in which area is substituted for flavor as a cue for control of food intake (Sclafani, 1991). Post-ingestive effects of foods that are signaled by energy density are strong inhibitors of eating (Blundell & Gillett, 2001) and can induce learned responses (Sclafani, 1995) that influence future eating patterns. Thus, the pathway from perception of visual properties of foods to an emotional response could be a learned association between the visual size of portions and the post-ingestive effects of their energy content. In this study, the greater the energy per unit area in a food, the greater was its anxiety-inducing potential, probably because anxiety is related to the potential for weight gain inherent in food energy (Steinglass, et al., 2010).

4.2 Limitations

Given the exploratory nature of this study, the sample of foods was small and with limited variability, in the interest of keeping the task brief. Other food attributes such as a food's texture, color, and flavor profile may also influence response to food portions. Our methods were not developed to be sufficiently comprehensive in accounting definitively for all variance in anxiety responses. Further research should account for other dimensions of food, such as palatability, familiarity, and perceived healthfulness, among others. Foods chosen for portion size research should also include a wider range of flavor profiles (i.e. sweet versus salty), food types (snack versus meal), and energy densities to increase the generalizability of results. A further limitation is that although the use of images of foods in lieu of actual food portions was successful in ensuring participants' full cooperation, this method limits the generalizability of the findings to real eating behaviors. Finally, since severity of illness was only moderate in this sample (~17 kg/m^2), these results might underestimate the extent to which calories per unit area can produce anxiety in patients with anorexia nervosa. In the present analysis, the interval between participants' last meal and testing was not standardized. However, an analysis of covariance showed that there was no effect of deprivation interval on any of the study measures (Kissileff, et al. 2016).

4.3 Conclusion

Although the present study utilized a limited array of food types, the results demonstrated that area is a critical variable for interpreting the effects of portion size on anxiety in patients with anorexia nervosa, and may be of more utility than measuring portion sizes solely by energy content. We have demonstrated that the magnitude of the anxiety expected from foods will differ depending on which attribute is used as the measuring rod. However, additional research will be necessary to determine whether the causal chain identified statistically will replicate in future research when areas and energy contents are independently assessed. As of now, it is not known precisely how the proposed conditioning process affects the anxiety expected in response to either dimension (area or energy) of stimulus intensity. Further research claims about the effects of portion size on cognitive and emotional responses that underpin food-related decision-making should take area into account to make claims about the

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FIGURE LEGENDS

Fig. 1. Images of portions shown to participants with their energy content shown below. Two pairs of almost equal sized images elicited equivalent anxiety responses are circled for comparison. The solid circles are for pizza (area = 63.9 cm^2) and rice (61.3 cm^2) which elicited a response of 50 mm out of 100 mm on a visual analogue scale for expected anxiety. The dotted circles show equal sized portions of M&M's and potatoes both of which elicited the same anxiety response (35 mm out of 100mm).

Fig. 2. Regression of standardized anxiety response from energy content of increasing portions by food. A key to the lines corresponding to foods is shown below the plot.

Fig. 3. Regression of standardized anxiety response from areas by food. A key to the lines corresponding to foods is shown below the plot.

Table 1.

Areas (cm^2) of Foods by Energy Content (kcal)

Food	20 kcal	40 kcal	80 kcal	160 kcal	320 kcal
Potatoes	11.72	23.45	46.9	93.8	187.6
Rice	15.99	31.97	63.95	127.9	255.79
Pizza	7.67	15.35	30.7	61.39	122.79
M&Ms	3.07	6.13	12.27	24.54	49.07

Table 2.

Model Comparisons of Regression Slopes of Expected Anxiety (EA) Response by Portion Size

		Model 1		Model 2		Model 3		Model 4	
R-Square		**0.77*****		**0.77*****		**0.77*****		**0.77*****	
		Slope	**SE**	**Slope**	**SE**	**Slope**	**SE**	**Slope**	**SE**
Food									
	Potatoes	**0.86*****	0.05	**0.96*****	0.05	**1.57*****	0.44	-0.001	0.31
	Rice	**0.83*****	0.05	**0.67*****	0.04	**1.11*****	0.32	-0.35	0.42
	Pizza	**0.50*****	0.05	**0.85*****	0.08	**1.78****	0.68	-0.06	0.21
	M&Ms	**0.41*****	0.05	**1.75*****	0.21	**4.08***	1.69	**0.18***	0.09
Differences between foods									
	Rice - Potatoes	-0.03	0.07	**-0.29*****	0.07	**-0.46*****	0.14	**-0.35****	0.13
	Pizza - Potatoes	**-0.36*****	0.07	**-0.11***	0.10	0.21	0.25	-0.06	0.13
	Pizza - Rice	**-0.32*****	0.07	0.18	0.09	0.67	0.37	0.29	0.23
	M&Ms - Potatoes	**-0.45*****	0.07	**0.79*****	0.21	**2.51***	1.26	0.19	0.24
	M&Ms - Rice	**-0.42*****	0.07	**1.08*****	0.21	**2.97***	1.38	0.53	0.34
	M&Ms – Pizza	-0.09	0.07	**0.90*****	0.22	**2.29***	1.03	0.24	0.14

Signif. codes: '***' <0.001 '**' <0.01 '*' <0.05 ' ' >.05
(all significant coefficients up to p < 0.05 are shown in **bold**)

Units are in z-scores obtained by standardizing both the dependent variable (anxiety response) and covariates (areas and energy).

Table 3.

Independent Contributions of Food, Energy, and Food by Energy Interaction on Expected Anxiety

Variable	DF	Type III SS	F	Pr > F	Semi-partial η^2	Upper - Lower 95% CL
Participant	23	180.78	27.08	<.0001	0.315	.215 - 0.346
Food	3	17.55	20.38	<.0001	0.031	.005 - 0.062
Kcal	1	2.82	9.82	0.002	0.005	0 - 0.025
Area	1	16.15	56.26	<.0001	0.028	.006 - 0.063
Kcal by Area	1	2.59	9.02	0.003	0.005	0 - 0.024

Units are in z-scores obtained by standardizing both the dependent variable (anxiety response) and covariates (areas and energy).

FIGURES

Figure 1.

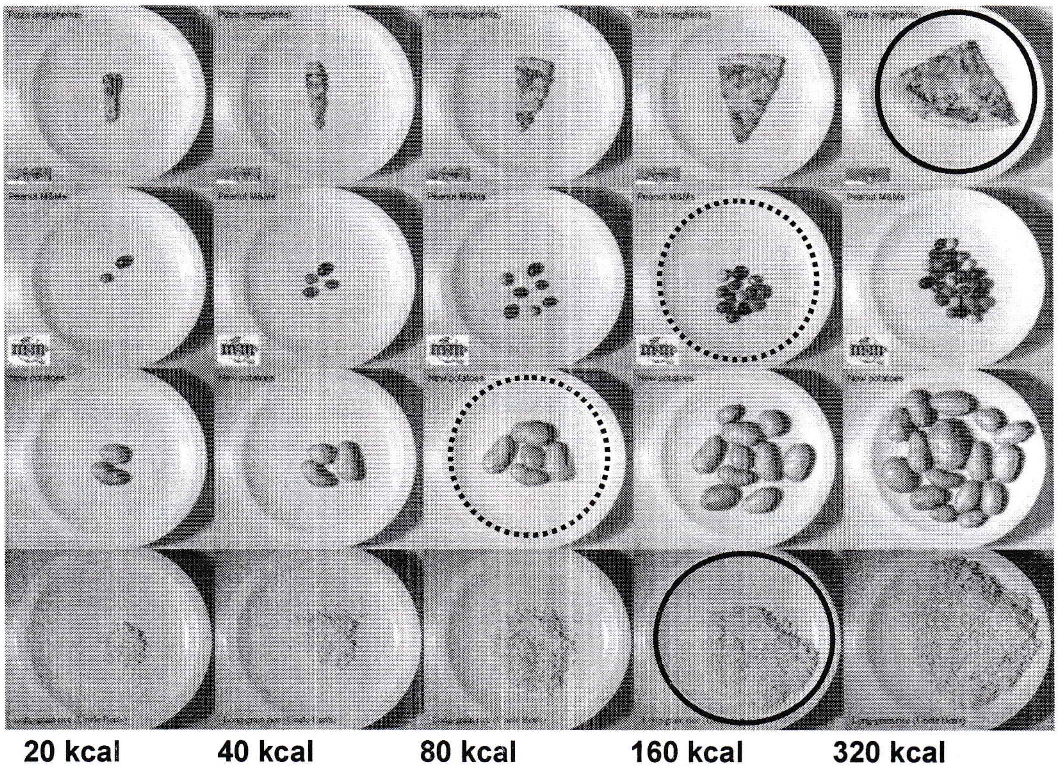


Figure 2.

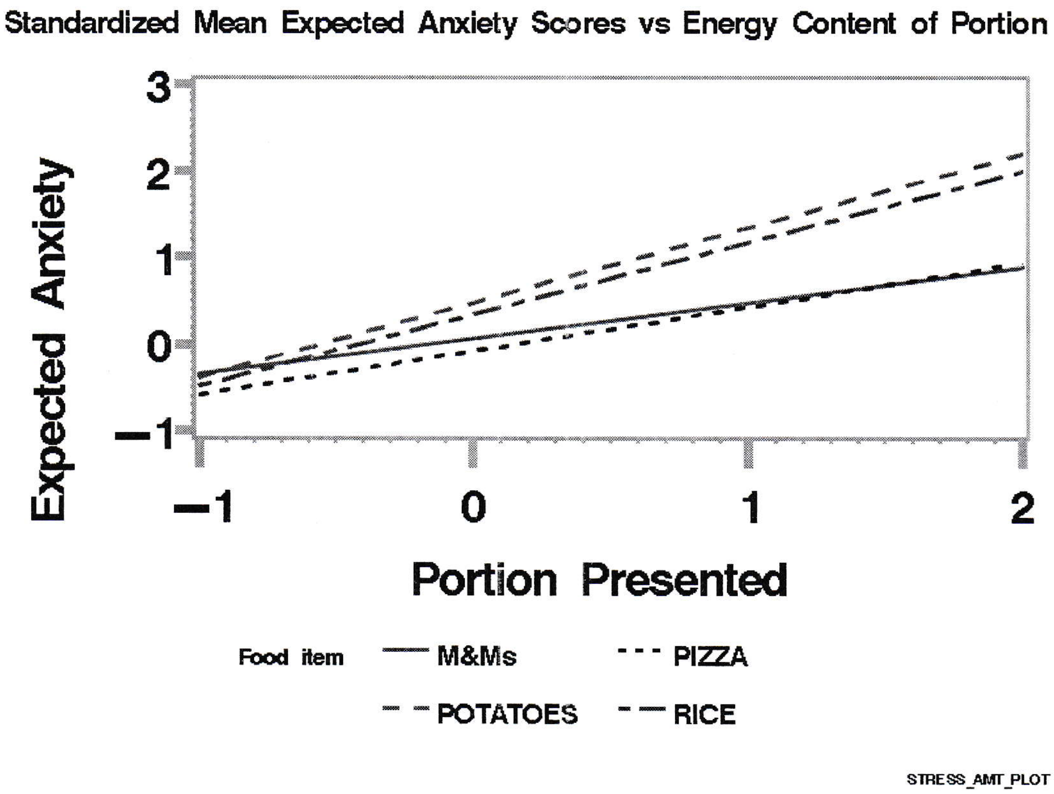
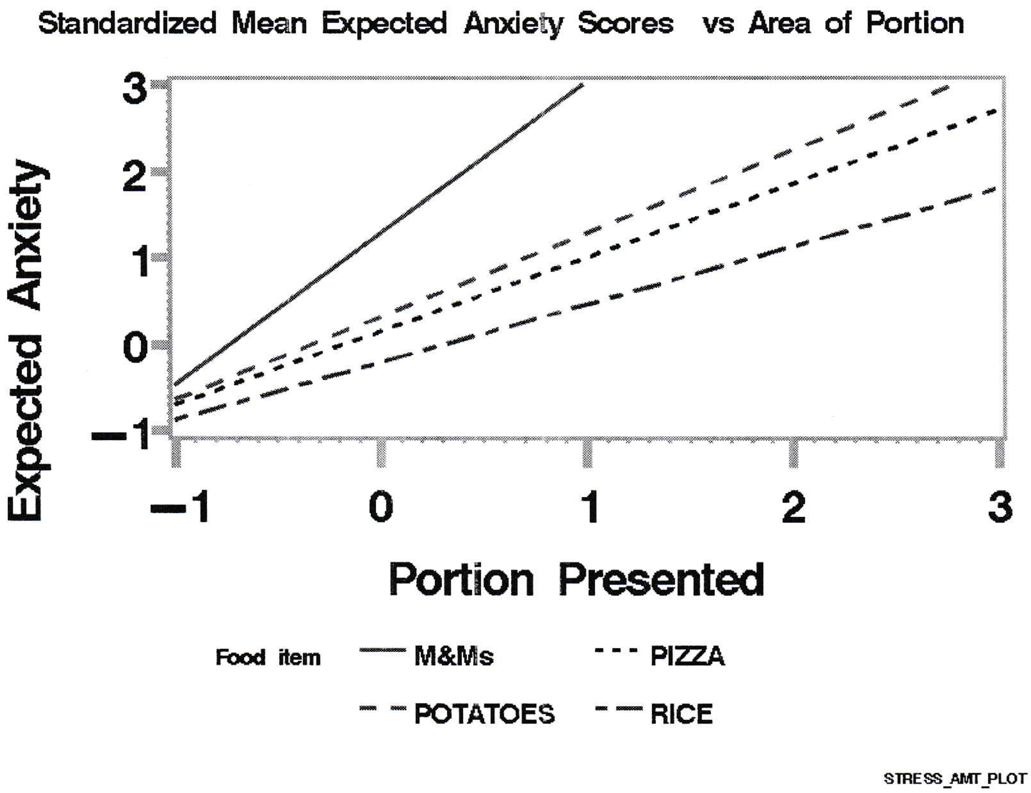

Standardized Mean Expected Anxiety Scores vs Energy Content of Portion
Expected Anxiety
3
2
1
0
−1
−1
0
1
2
Portion Presented
Food item
M&Ms
PIZZA
POTATOES
RICE
STRESS_AMT_PLOT

Figure 3.


Standardized Mean Expected Anxiety Scores vs Area of Portion
Expected Anxiety
3
2
1
0
—1
—1
0
1
2
3
Portion Presented
Food item
M&Ms
PIZZA
POTATOES
RICE
STRESS_AMT_PLOT