Brain Responses to Food Logos in Obese and Healthy Weight Children

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Objective To evaluate brain activation in response to common food and nonfood logos in healthy weight and obese children.

Study design Ten healthy weight children (mean body mass index in the 50th percentile) and 10 obese children (mean body mass index in the 97.9th percentile) completed self-report measures of self-control. They then underwent functional magnetic resonance imaging while viewing food and nonfood logos.

Results Compared with the healthy weight children, obese children showed significantly less brain activation to food logos in the bilateral middle/inferior prefrontal cortex, an area involved in cognitive control.

Conclusion When shown food logos, obese children showed significantly less brain activation than the healthy weight children in regions associated with cognitive control. This provides initial neuroimaging evidence that obese children may be more vulnerable to the effects of food advertising. *(J Pediatr 2013;162:759-64)*.

See editorial, p 672

An environmental factor implicated in overeating—and ultimately obesity—is food marketing.[1] Every year, food and beverage companies spend more than $10 billion to market their products to children in the US.[2] The goal of these marketing efforts is to establish brand recognition, brand preference, and brand loyalty at a young age. Studies have shown that advertising is an effective means to this end. Research examining the effects of television food advertising on children has shown that children exposed to television advertisements will prefer advertised foods at higher rates than those not exposed to advertisements.[3] For example, one study found that preschoolers reported that foods wrapped in branded packaging tasted better than the same foods wrapped in generic packaging.[4] In addition, the amount of children's exposure to advertisements is directly correlated with the number of attempts they make to influence parents' purchases.[3]

A downside to food marketing is that advertising exposes children to unhealthy foods more frequently than healthy foods.[5] One study found an association between exposure to advertisements for energy-dense and micronutrient-poor foods and an increased risk of obesity in children.[6] Another study determined that compared with healthy weight children, overweight children consume significantly more calories in brand name foods versus generic foods.[7] These findings suggest that children carrying excess weight may be more responsive to food branding and thus at greater risk for marketing persuasion.

Functional neuroimaging studies examining brain activation in response to food images have identified brain regions related to both reward (limbic and paralimbic regions) and cognitive control (prefrontal cortices) in children.[8-11] However, to date few neuroimaging studies have examined brain activation to culturally familiar brands, and only one study has looked at food-related brands. Moreover, all of these studies have focused on healthy adults viewing culturally familiar logos. Findings have identified the dorsolateral prefrontal cortex (PFC), ventromedial PFC, orbitofrontal cortex (OFC), anterior cingulate cortex, ventral striatum, and hippocampus as involved in brand recognition.[12-16] Several of these areas—PFC, OFC, anterior cingulate cortex, ventral striatum, and hippocampus—are also involved in aspects of food motivation (both the "drive" and the "control" regions) and have been identified in functional magnetic resonance imaging (fMRI) studies that examined the cortical foundations of overeating and obesity.[8,10,17-19]

The aim of the present study was to compare neural responses to brand logos in obese and healthy weight children as they viewed food brand and nonfood brand logos. We hypothesized that children would demonstrate greater brain activation to food logos in "drive" regions (ie, ventral striatum and OFC) compared with the healthy weight children, and that the healthy weight children would demonstrate greater brain activation to food logos in "control" regions (ie, PFC) compared with the obese children.

fMRI	Functional magnetic resonance imaging
OFC	Orbitofrontal cortex
PFC	Prefrontal cortex

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Methods

The protocols for the pilot validation study and the main fMRI study were reviewed and approved by the Human Subjects Committee at the University of Kansas Medical Center. Before participation, written informed consent was obtained from each child's parent/legal guardian and written informed assent was obtained from each child.

A pilot validation study was first conducted to select the most appropriate logos for use in the fMRI study. Thirty-two children (13 males) aged 9-16 years (mean ± SD, 11.5 ± 2.2 years) used a 5-point Likert scale to rate 239 culturally familiar brand logos on 3 dimensions: familiarity, valence (happy/sad), and arousal (exciting/boring) (Figure 1). The Likert scale used was the same one used in stimulus validation studies for the International Affective Picture Set.[20] Based on the children's ratings, 60 food logos and 60 nonfood logos rated highly familiar were selected. Food logos as a group were matched on familiarity with nonfood logos [$t(118) = 0.33$; $P = .74$]. The food and nonfood logos were not significantly different on valence [$t(118) = 1.26$; $P = .21$] or arousal [$t(118) = 1.49$; $P = .14$]. A total of 120 logos were used in the fMRI paradigm in the main study (Table I; available at www.jpeds.com). Blurred baseline images were created from the food and nonfood logos using 3 iterations of a fast Fourier transform, rendering the logos unidentifiable (Figure 1); thus, the blurred baseline images were matched to the logos based on color, brightness, and intensity.

Twenty children (11 females), aged 10-14 years (mean, 11.85 ± 1.23 years), were recruited from local pediatric clinics and e-mails sent to University of Kansas Medical Center employees. All children were right-handed and in an age-appropriate grade. Exclusion criteria included participation in the pilot validation study, a major psychiatric diagnosis (eg, depression, attention deficit hyperactivity disorder) or neurologic illness (as determined by parental interview), and uncorrected impaired vision. All children spoke English as their primary language. Ten children were of healthy weight (mean body mass index percentile, 50.0 ± 19.7%), and 10 children were obese (mean body mass index percentile, 98.9 ± 1.7). There were no significant differences between the 2 weight groups in terms of age [$t(18) = 0.91$; $P = .38$], sex [$\chi^2 = 1.82$; $P = .18$], or parental income [$t(18) = 1.18$; $P = .26$].

The children and their parents completed several questionnaires, including those eliciting demographic data and self-control measures. Children were weighed and measured at the visit. Self-control was assessed using the impulsivity subscale of the 23-item Eysenck I6 Junior Questionnaire, which was created exclusively for use in children.[21] In this questionnaire, responses are "yes" or "no" to questions such as: "Do you generally do or say things without stopping to think?" None of the items specifically relate to eating behaviors or food. Higher scores on the measure are indicative of greater impulsivity.

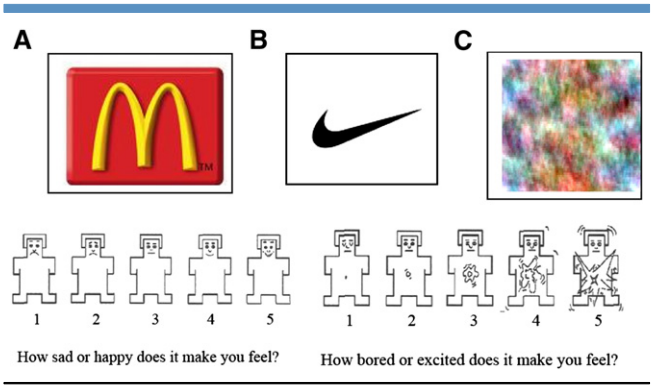

Figure 1. **A** and **B,** Examples of items from the pilot validation of logos before the main fMRI study. **C,** Example of blurred logo. Logos are registered trademarks and are the property of their respective owners.

The fMRI study was conducted at a minimum of 4 hours after the child's last food intake. Before the study, the procedure was fully explained to the child and parents, and the child provided a self-report hunger rating on a visual analog scale. The fMRI experiment consisted of a structural scan followed by 2 functional runs. The entire scanning session took approximately 45 minutes.

Data were acquired with a 3-T Allegra scanner (Siemens, Erlangen, Germany) at the University of Kansas Medical Center's Hoglund Brain Imaging Center. T1-weighted anatomic images were acquired with a 3-dimensional (3D) magnetization-prepared rapid acquisition with gradient echo sequence (repetition time/echo time = 23/4 ms, flip angle = 8°, field of view = 256 mm, matrix = 256 × 192, slice thickness = 1 mm). Each scan consisted of one anatomic scan and two 6-minute, 36-second functional sequences. Gradient echo blood oxygen level-dependent scans were acquired in 43 contiguous axial slices at an angle of 40° to the anterior commissure–posterior commissure line (repetition time/echo time 3000/30 ms, slice thickness = 3 mm [0.5 mm skip], in-plane resolution = 3 × 3 mm, 130 data points). To minimize susceptibility artifact in ventromedial prefrontal regions, all participants were carefully positioned so that the anterior commissure–posterior commissure plane was between 17° and 22° from axial in scanner coordinate space, ensuring that the 40° slice acquisition angle was applied in the same way for all subjects. In addition to minimizing susceptibility artifact, this procedure standardized head positioning between subject groups of widely divergent size (healthy weight and obese).

Using a previous study's block design, the 60 food logos, 60 nonfood logos, and blurred baseline images were displayed.[8] Each logo was presented only once to each participant. Functional scans involved 3 repetitions of each block of each stimulus type (ie, food logos), alternated between blocks of blurred images. Stimulus presentation time was

2.5 seconds, with a between-stimulus interval of 0.5 seconds. The 2 functional scans consisted of 13 blocks of stimuli presentation, with 10 logos in each block. The order of category presentation was counterbalanced across participants. Visual images were back-projected to a screen mounted on the back of the magnet, and the child viewed the images through a mirror on the head coil. Foam cushions were placed around the child's head to minimize movement.

Data preprocessing and statistical analyses were conducted using Brain Voyager QX (Brain Innovation, Maastricht, The Netherlands). The preprocessing steps included trilinear 3D motion correction, sinc-interpolated slice scan time correction, 3D spatial smoothing (4-mm Gaussian filter), and high-pass filter temporal smoothing. Functional images were realigned to the anatomic images obtained within each session and normalized to the BrainVoyager template image, which conforms to the space defined by the Talairach and Tournoux stereotaxic atlas.[22] All functional runs met our acceptance criterion of <3 mm of movement on any axis (x, y, or z).

Activation maps were generated using statistical parametric methods and random effects in Brain Voyager QX. Statistical contrasts were conducted using multiple regression analysis with the general linear model, allowing multiple predictors to be built into the model. Regressors representing experimental conditions of interest were modeled with a hemodynamic response filter and entered into the multiple regression analysis using a random-effects model. Contrasts between conditions of interest were assessed with t statistics across the whole brain. Voxel values were considered significant if the activation survived a statistical cluster–based threshold of $P < .01$, corrected. We corrected for multiple comparisons using the familywise approach ($\alpha < 0.05$; $P < .01$; $k = 9$ voxels), determined by Monte Carlo simulation.[23,24]

Results

The obese group reported significantly more impulsivity on the Eysenck Impulsivity Scale (mean, 13.2 ± 3.65) than the healthy weight group (mean, 8.4 ± 5.62) as determined by an independent-samples t test [$t(18) = -2.27$; $P = .036$]. There was no significant difference in self-reported hunger between the obese and healthy weight groups [$t(18) = 1.28$; $P = .217$].

In the group (healthy weight, obese) × stimulus type (food, baseline) interaction, the healthy weight group showed greater brain activation to food logo versus baseline pictures in the middle frontal gyrus and middle temporal gyrus (**Table II**; available at www.jpeds.com). The obese group showed greater brain activation in the postcentral gyrus and midbrain (**Figure 2**).

In the group (healthy weight, obese) × stimulus type (nonfood, blurred baseline) interaction, the healthy weight group did not show significantly greater brain activation than the obese group in any region. The obese group showed greater brain activation in the thalamus, inferior frontal gyrus, insular cortex, and cuneus (**Table III**; available at www.jpeds.com).

In the group (healthy weight, obese) × stimulus type (food logo, nonfood logo) interaction, the healthy weight group showed greater brain activation to food logos versus nonfood logos in the middle and inferior frontal gyrus, superior temporal gyrus, parahippocampal gyrus, and insula (**Table IV**). The healthy weight group also demonstrated greater

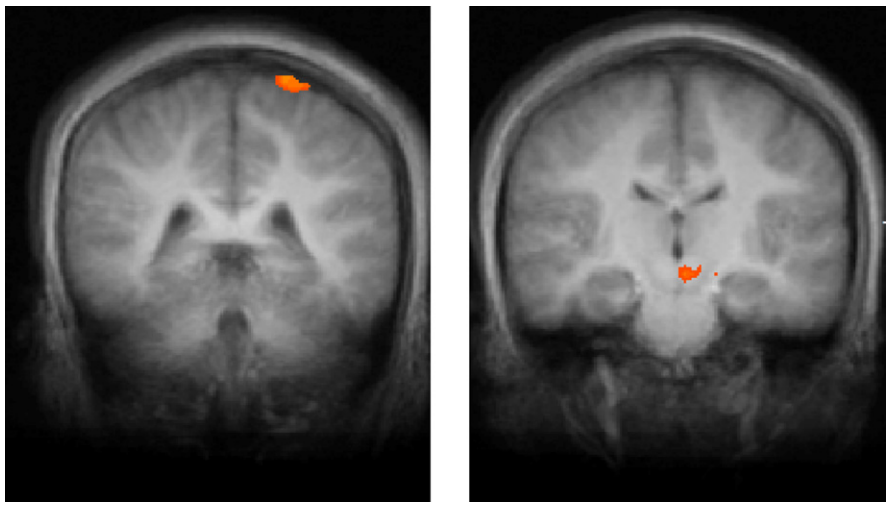

Figure 2. fMRI statistical maps (coronal perspectives) showing results from between groups food versus blurred baseline contrasts, coregistered with average structural magnetic resonance imaging data from participants. Significance thresholds are set at $P < .01$, corrected. Highlighted areas indicate greater activation in the left postcentral gyrus (*left*) and midbrain (*right*) in the obese group compared with the healthy weight group.

Table IV. Regions reaching significance for the contrasts between food and nonfood logo stimuli categories between groups ($P < .01$, corrected, random effects)

Contrast and region	Coordinate				Contiguous voxels
	x	*y*	*z*	*t*	
Healthy weight > obese					
Right superior temporal gyrus Brodmann area 22	48	5	−2	5.12	43
Right superior temporal gyrus Brodmann area 39	52	−52	10	4.26	12
Right inferior frontal gyrus	36	44	4	6.25	17
Right parietal precuneus Brodmann area 7	6	−55	64	4.15	14
Left parietal precuneus Brodmann area 7	−21	−67	40	4.28	42
Left superior parietal Brodmann area 7	−21	−61	58	6.12	24
Left parahippocampal gyrus Brodmann area 36	−24	−43	−8	6.04	11
Left parietal Brodmann area 7	−24	−49	52	4.32	17
Left middle frontal gyrus Brodmann area 10	−42	44	−5	6.27	29
Left insula Brodmann area 13	−51	−19	22	5.46	9
Obese > healthy weight: none					

bilateral activation in Brodmann's area 10 extending to the inferior frontal gyrus (Figure 3). In contrast, the obese group did not show any significantly greater brain activation than the healthy weight group.

Discussion

The present study examined children's responses to logos using fMRI. Some of our results are consistent with previous adult fMRI studies examining responses to logos. Adult fMRI studies have demonstrated significant brain activations in the PFC, limbic system, hippocampus, and paralimbic cortex.[12-16] In this study, we observed significant areas of activation to food and nonfood logos in the middle and inferior PFC.

Our results are also consistent with those obtained by previous fMRI studies examining food motivation in children.[8-10] The areas of children's brains that were activated in response to food logos (ie, middle and inferior PFC) overlap with areas identified in previous studies examining brain activation in response to actual images of food.[8-10]

We found partial support for our first hypothesis. Obese children demonstrated greater activation in reward regions when shown food logos compared with baseline blurred images. However, the specific reward areas differed from the regions commonly cited in the food motivation literature. Specifically, we did not find significantly greater brain activation in the OFC or ventral striatum, which have been identified in previous food motivation neuroimaging studies.[8-11] Instead, we noted brain activation in older structures, including the midbrain. Interestingly, a recent study of adults who underwent bariatric surgery found decreased activation in the midbrain in response to hedonic food images, associated with the postsurgical weight loss.[25] The authors postulated that these postsurgical changes may be related to the patients' perception of a reduced reward value of food.

As expected, when viewing food logos, the healthy weight children demonstrated greater brain activation in regions associated with cognitive control and self-control regions compared with the obese children. Specifically, Brodmann's area 10 and the inferior frontal gyrus showed greater activation bilaterally in healthy weight children. A growing body of evidence supports an integral role of the inferior frontal gyrus in self-control and inhibition.[26,27] It is possible that, although all children demonstrate brain activation in motivational/reward regions on exposure to familiar logos, healthy weight children show greater restraint than obese children. Behavioral studies have found that when allowed unrestricted food consumption, obese children ate significantly more calories of brand-name items compared with unbranded items, but healthy weight children did not.[7] Our neuroimaging data complement these behavioral findings. Moreover, in the present study, the obese children self-reported significantly greater impulsivity compared with the healthy weight children. It should be noted that obese children showed significantly greater activation in the inferior frontal gyrus in response to nonfood logos. This raises the question of whether obesity is associated with lower levels of generalized self-control or whether it is specific to food cues. One limitation of the present study was that we did not administer a questionnaire eliciting information on impulsivity related to food.

This study has some other limitations as well. First, our sample size is relatively small, and thus our findings should be considered preliminary. Future studies with larger samples would permit examination of age and sex effects in response to brands. Second, because of the need to match the food and nonfood logos on familiarity, valence, and intensity, the logos selected for the imaging paradigm were not rated the most familiar and "happiest" food logos, and thus our findings might underemphasize the effects of food logos on children's brain responses. Third, logo ratings of familiarity, valence, and intensity were provided by a different sample of children. Future studies should have children rate the logos while in the scanner. Finally, decreased brain activation in a region does not necessarily mean that this region is exerting less influence. In fact, reduced activation can occasionally demonstrate more efficient neural processing, or deactivation of inhibitory networks. In our results, however, the self-report measure

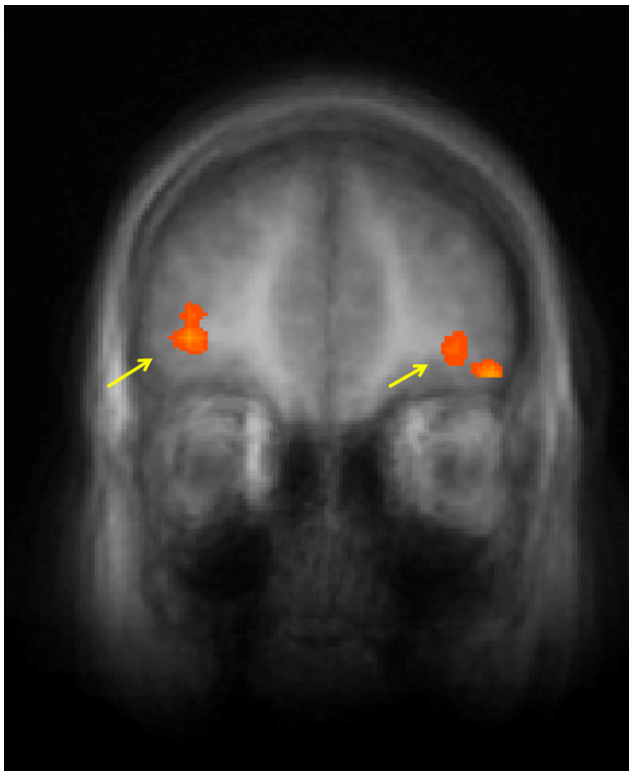

Figure 3. fMRI statistical maps (coronal perspective) showing results from between groups food versus nonfood contrasts, coregistered with average structural magnetic resonance imaging data from participants. Significance thresholds are set at $P < .01$, corrected. *Arrows* highlight greater activation in bilateral Brodman area 10, extending to the inferior frontal gyrus in the healthy weight group compared with the obese group.

of impulsivity (ie, obese children reporting significantly less self-control) corroborates the fMRI findings. The differences between brain activation to food logos in obese and healthy weight children are not likely due to food motivation, given that self-reported hunger was not significantly different between the 2 groups.

Our findings are strengthened by a converging body of neuroimaging evidence suggesting greater activation in control regions in healthy weight individuals compared with obese individuals.[8] One key to improving health-related decision making may lie in the ability to improve cognitive and self-control. Mischel et al[28] demonstrated the enduring positive effects of the ability to delay rewards at a young age. Recent studies have shown that body mass index and the ability to delay gratification are negatively related in children.[29,30] Including self-control training with obesity and behavioral health interventions may lead to greater success. Future research should examine children's brain activation in response to food images and food logos before and after obesity interventions. ■

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Table I. Food and nonfood logos in fMRI paradigm, sorted by familiarity (highest at top)

Food logos	Nonfood logos
Drpepper.bmp	lego.bmp
pizzahut.bmp	honda.bmp
cokebottle.bmp	spongebob.bmp
wendys.bmp	FedEx.bmp
cheeto.bmp	hallmark.bmp
dominos.bmp	ku.bmp
McDM.bmp	flag.bmp
starbucks.bmp	winnie the pooh.bmp
tacobell.bmp	garfield.bmp
7up.bmp	mickey mouse.bmp
bk.bmp	bestbuy.bmp
crunch.bmp	pokemon.bmp
doritos.bmp	oldnavy.bmp
ljs.bmp	sprint.bmp
mug.bmp	wb.bmp
oreo.bmp	crayola.bmp
sonic.bmp	crest.bmp
fritos.bmp	Lowes.bmp
ritz.bmp	nike.bmp
trix.bmp	nintendo.bmp
wonder.bmp	Playstation.bmp
chipsahoy.bmp	windows.bmp
yoplait.bmp	goodyear.bmp
dunkindonuts.bmp	redcross.bmp
jellybelly.bmp	verizon.bmp
tgifridays.bmp	abc.bmp
kfc.bmp	cathat.bmp
luckycharms.bmp	dell.bmp
mrpeanut.bmp	duracell.bmp
nesquik.bmp	elmo.bmp
pepsi.bmp	energizer.bmp
quakerlogo.bmp	lionking.bmp
tostitos.bmp	nfl.bmp
aquafina.bmp	bugsbunny.bmp
caprisun.bmp	nba.bmp
chilis.bmp	royals.bmp
lays.bmp	snoopy.bmp
snapcracklepop.bmp	VISA.bmp
v8.bmp	elmers glue.bmp
blowpop.bmp	dodge.bmp
frostedflakes.bmp	DVD.bmp
greengiant.bmp	mlb.bmp
nestea.bmp	bartsimpson.bmp
pillsbury.bmp	disneycastle.bmp
ricekrispees.bmp	dove.bmp
keeblerelf.bmp	tommyhilfiger.bmp
ruffles.bmp	chevy.bmp
minutemaid.bmp	colgate.bmp
capncrunch.bmp	jeep.bmp
dasani.bmp	directTV.bmp
dole.bmp	gap.bmp
cheeriosbee.bmp	Mizzou.bmp
chefboy.bmp	kstate.bmp
wheatthins.bmp	kermit.bmp
dannon.bmp	nbc.bmp
folgers.bmp	walmart.bmp
crackerjack.bmp	bp.bmp
hostess.bmp	mercedes.bmp
kraft.bmp	bmw.bmp
triscuit.bmp	puma.bmp

Table II. Regions reaching significance for the contrasts between food and baseline logo stimuli categories between groups ($P < .01$, corrected, random effects)

Contrast and region	Coordinates				Contiguous voxels
	x	*y*	*z*	*t*	
Healthy weight > obese					
Right middle frontal gyrus	36	25	19	5.11	23
Left middle frontal gyrus Brodmann area 10	−27	42	7	4.04	11
Left middle temporal gyrus Brodmann area 39	−48	−55	13	4.27	11
Left temporal lobe fusiform gyrus Brodmann area 3	−48	−31	−17	4.39	12
Right cerebellum	9	−67	−38	3.84	9
Obese > healthy weight					
Left midbrain/substantia nigra	−3	−19	−8	4.09	10
Left postcentral gyrus Brodmann area 3	−21	−37	70	5.10	13

Table III. Regions reaching significance for the contrasts between nonfood and baseline logo stimuli categories between groups ($P < .01$, corrected, random effects)

Contrast and region	Coordinate				Contiguous voxels
	x	*y*	*z*	*t*	
Healthy weight > obese: none					
Obese > healthy weight					
Right inferior frontal gyrus Brodmann area 47	30	35	1	4.95	12
Right thalamus	15	−31	4	5.02	25
Right thalamus	3	−13	7	4.25	12
Right occipital cortex cuneus Brodmann area 17	15	−94	1	4.03	13
Left insula Brodmann area 13	−33	−19	19	4.26	10
Right brainstem/dorsal raphe nuclei	3	−28	−17	4.25	11