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ORIGINAL ARTICLES

The Influence of Televised Food Commercials on Children's Food Choices: Evidence from Ventromedial Prefrontal Cortex Activations

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Objective To investigate how food commercials influence children's food choices.

Study design Twenty-three children ages 8-14 years provided taste and health ratings for 60 food items. Subsequently, these children were scanned with the use of functional magnetic resonance imaging while making food choices (ie, "eat" or "not eat") after watching food and nonfood television commercials.

Results Our results show that watching food commercials changes the way children consider the importance of taste when making food choices. Children did not use health values for their food choices, indicating children's decisions were largely driven by hedonic, immediate rewards (ie, "tastiness"); however, children placed significantly more importance on taste after watching food commercials compared with nonfood commercials. This change was accompanied by faster decision times during food commercial trials. The ventromedial prefrontal cortex, a reward valuation brain region, showed increased activity during food choices after watching food commercials compared with after watching nonfood commercials.

Conclusion Overall, our results suggest watching food commercials before making food choices may bias children's decisions based solely on taste, and that food marketing may systematically alter the psychological and neurobiologic mechanisms of children's food decisions. *(J Pediatr 2016;■■:■■-■■).*

See related article, p •••

Each year, the food industry spends 1.8 billion dollars marketing its products to children and adolescents.[1] It has been estimated that 2- to 5-year-old children view more than 1000 advertisements per year, and adolescents see almost 2000.[2] Food marketing is cited as a significant environmental factor implicated in food choices, overeating, and ultimately, obesity.[3,4]

Television advertising and branding have an effect on both food familiarity and preference. Research examining the effects of television food advertising on children has shown that children exposed to advertisements prefer branded foods at much greater rates than children not similarly exposed. Television advertising impacts food consumption and eating behaviors as well. Behavioral studies have documented the relationship between receptivity to food commercials and the amount of food consumed.[5] For example, snack and sweet food intake increases during or after commercial viewing in children.[6,7] Children who are overweight may be more responsive to food branding and therefore at greater risk for marketing persuasion. There is some behavioral and epidemiologic research that demonstrates an association between marketing for unhealthy foods and increased risk for childhood obesity.[7]

Advertising cues do not impact all children in the same way. For example, Bruce et al[8] documented individual differences in brain activation in response to food advertising cues (ie, fast food brand logos). When observing food brand logos, obese children demonstrate reduced neurofunctional reactivity in the prefrontal cortex, a cortical region known to be associated with self-control.

The purpose of this study was to examine children's food decision processes and brain activity during active food selections. We specifically sought to determine whether choices and/or brain activations were in any way altered after the viewing of typical food commercials. We hypothesized that food commercials would bias the children to make more taste-oriented choices. For brain analyses, our primary focus was on the brain region most active during reward valuation—the ventromedial prefrontal cortex (vmPFC). We hypothesized that, after the children viewed food commercials, activity in their vmPFC would increase while they made specific food choices.

BMI	Body mass index
CF	Commercial films
fMRI	Functional magnetic resonance imaging
GLM	General linear models
ROI	Region of interest
vmPFC	Ventromedial prefrontal cortex

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Methods

Twenty-three children between the ages of 8 and 14 years (mean = 10.5 years old; 11 boys) completed the study. Two additional children participated in a subset of the tasks but were excluded from further analyses because of behavioral or technical problems (ie, noncompliance to task instructions and incomplete decision tasks). Before participation, all children provided their assent, and their mothers provided their informed consent, as approved by the Human Subjects Committee of the University of Kansas Medical Center. Participants were in good health, right-handed, had normal or corrected-to-normal vision, and had no history of attention deficit hyperactivity disorder, psychiatric diagnoses, or neurologic or metabolic illnesses. Children were not taking any psychotropic medications and reported no history of lactose intolerance or allergies to any of the food items used in the experiment.

Participants were instructed not to eat for 3 hours before the experiment session to ensure heightened food motivation at the time of the food decision task. After arriving at the brain imaging center, children's heights and weights were measured with a stadiometer (PE-WM-60-84; Perspective Enterprises, Portage, Michigan) and scale (PS6600 ST; Befour, Saukville, Wisconsin) to calculate body mass index (BMI; kg/m^2). The BMI scores were converted to age- and sex-adjusted BMI percentile scores (mean = 56.1, SD = 29.8, range 6.2-97.1). Then, before behavioral tasks, participants self-reported their hunger levels using an 11-point visual analog scale ("how hungry do you feel right now?"; mean = 5.9, SD = 3.2).

Sixty food images were used for the behavioral food-rating task and functional magnetic resonance imaging (fMRI) food decision task. Images included 30 healthy food items (eg, apple, broccoli, asparagus) and 30 unhealthy food items (eg, glazed donut, French fries, marshmallows). All food pictures were high-resolution (72 dpi) color images with a size of 300 × 300 pixels.

Six food and 6 nonfood television commercials were used in our study. These stimuli were selected from a recent study that investigated neural responses to food commercials in adolescents.[9] Among the original 20 brands included in the study by Gearhardt et al,[10] we selected 12 brands (6 from each category) relevant to children (**Table I**). All commercials were 15 seconds in length and were shown at the beginning of each block in the fMRI food decision task. The type of commercial (ie, food or nonfood) shown first was counterbalanced across participants. Each brand commercial (640 × 480 pixels) was shown a total of 6 times (2 for each block condition in 2 different versions) throughout the experiment. After the fMRI study, desirability and familiarity ratings for each commercial were acquired separately via a 5-point Likert scale (**Table I**). Because of a technical malfunction, 1 participant's desirability and familiarity ratings were not recorded. The stimulus presentation and behavioral response collection were controlled by Presentation software (version 17; Neurobehavioral Systems, Berkley, California).

Table I. Commercial stimuli

Food commercials
Liking: mean = 3.63 (SD = .60)
Familiarity: mean = 4.11 (SD = .82)
(1) Applebee's
(2) Chili's Grill & Bar
(3) Denny's
(4) McDonald's
(5) Subway
(6) Wendy's
Nonfood commercials
Liking: mean = 3.15 (SD = .37)
Familiarity: mean = 3.56 (SD = .76)
(1) Allstate Insurance
(2) AT&T Phone Service
(3) Comcast Cable
(4) Ford Car Company
(5) T-Mobile Phone Service
(6) Verizon Phone Service

Before the food rating task began, all of the food images were introduced by the research staff to ensure participants were familiar with each of the foods. To ensure participants understood the food rating tasks, the task type was cued by an initial instruction display ("taste rating task" or "health rating task"), and a 4-point rating scale (ranging from "very bad" to "very good" or from "very unhealthy" to "very healthy") was presented below the food image during the rating decision period. Participants first provided separate ratings for taste attributes ("very bad," "bad," "good," or "very good") and health attributes ("very unhealthy," "unhealthy," "healthy," or "very healthy") for each food item presented on a laptop monitor via buttons on the keyboard. Participants provided ratings in 2 separate tasks (a taste rating task and a health rating task), and the order in which the 2 tasks were presented was counterbalanced across participants. For each food item, children were instructed to provide the taste rating regardless of health attributes, or to provide the health rating regardless of taste attributes. All rating runs were randomized and remained on the computer screen until a definite response was recorded. Rating trials were separated by a 1-second fixation cross screen. Because of a technical issue, 2 participants' behavioral ratings were not recorded, and thus their responses were excluded from further analyses requiring those data.

Inside the magnetic resonance imaging scanner, participants engaged in the food decision task (total scanner time of approximately 30 minutes). The food decision task included 3 different types of commercial film condition blocks ("Food Commercials," "Nonfood Commercials," and "No Commercials" conditions) that were presented randomly. Each block began with the participants watching one 15-second television commercial (Food Commercial, Nonfood Commercial, or blank screen), then was followed by 10 food decision trials (**Figure 1**). In food decision trials, children were asked to make decisions about how much they wanted to eat the food item presented on the screen.

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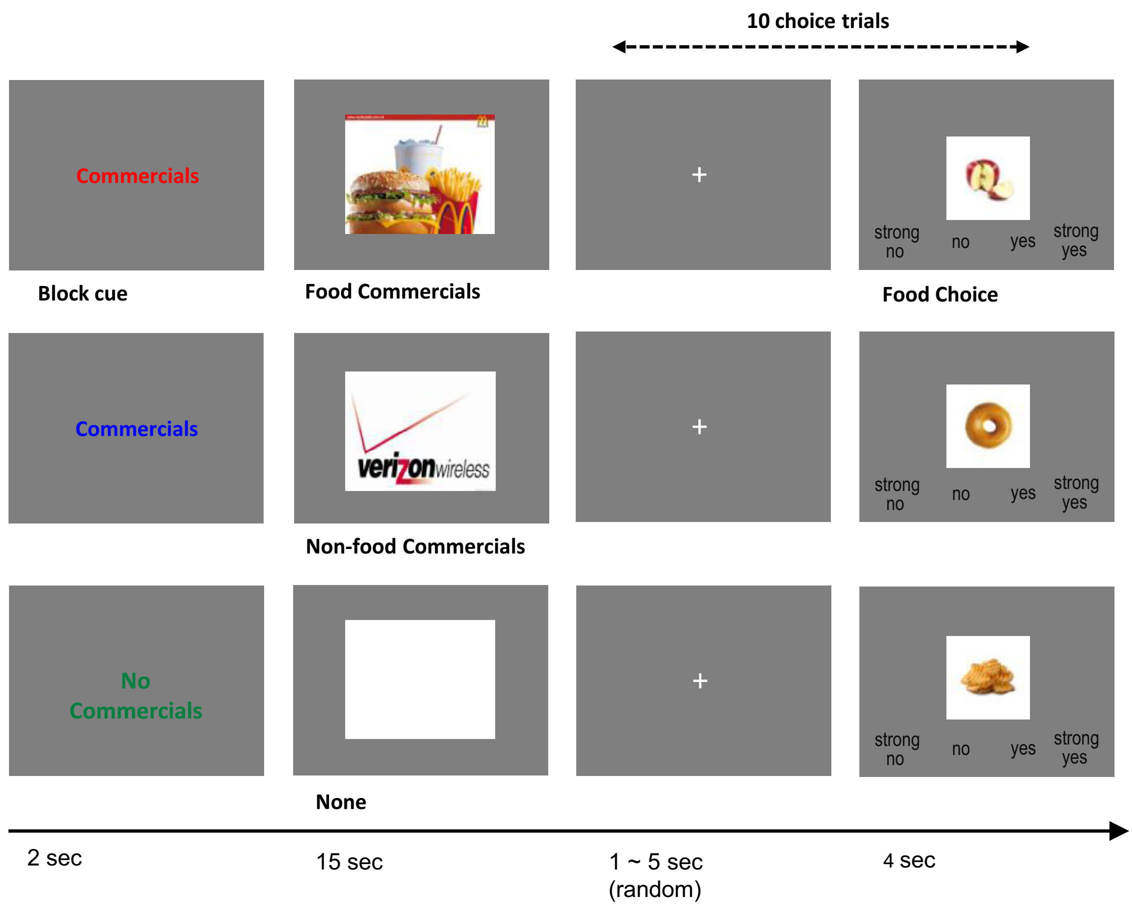

Figure 1. Food choice task consisted of 3 different commercial block conditions. Each block began with a block cue screen, and then was followed by 10 food choice trials. The order of blocks and food choices within a block were randomized. Children were asked to make food decision by using a 4-point scale ("strong no ~ strong yes" or "strong yes ~ strong no"; counterbalanced across participants).

To ensure participants' choices remained nonhypothetical and incentive-compatible throughout the task, participants were instructed and encouraged to make their food decisions as real choices, as one of these choices would be selected randomly, and the food item chosen would be given to them to eat at the end of the fMRI experiment. Participants completed 3 runs of the decision task, and each run included 2 food commercial blocks, 2 nonfood commercial blocks, and 2 no commercial blocks. The block type was cued by an initial 2-second instructional display. The order of blocks and the order of trials within each block were randomized fully. The randomization sequence was generated separately for each subject. Participants completed a total of 180 decision trials throughout the 3 blocks (60 choices for each type of commercial block). Participants were asked to enter their food decisions using a 4-point scale ("strong no," "no," "yes," or "strong yes") during a maximum time limit of 4 seconds, after which the presented food image disappeared from the screen. The decision scale was presented below the food image. To exclude motor-related responses of no interest in the fMRI data analyses, the response button mapping (from "strong no" to "strong yes" or from "strong yes" to "strong no") was counterbalanced across participants. Decision trials were separated by a fixation cross screen of random duration (uniform: 1-5 seconds).

Anatomical and functional scans were acquired with a Siemens 3-T Magnetom Skyra scanner (Siemens Medical Systems, Erlangen, Germany) with a 12-channel head coil at the Hoglund Brain Imaging Center of the University of Kansas Medical Center. Anatomical images were acquired first with a high-resolution MPRAGE sequence (1-mm isotropic voxel; 256-mm field of view). Next, blood oxygenation level-dependent contrast functional images were acquired with gradient-echo echo-planar T2*-weighted imaging. To optimize functional sensitivity of signals in the orbitofrontal cortex, T2* images were acquired in an oblique orientation of 35° to the anterior commissure-posterior commissure line. Each functional volume consisted of 48 axial slices (repetition time = 2530 milliseconds; echo time = 25 milliseconds; flip angle = 90°; field of view = 192 mm; 64 × 64 matrix; 3-mm isotropic voxel). A total of 585 volumes were acquired through 4 functional runs.

Analysis of fMRI data was performed with the AFNI package,[11] as well as custom MATLAB scripts. The first 2 functional volumes of each run were removed to account for the equilibration effects of magnetization. The following processing steps were applied sequentially: slice-time correction, motion correction, spatial resampling (3 × 3 × 3 mm) and normalization to the standard Talairach template,[12] Gaussian spatial smoothing (full width at half maximum: 6 mm), and intensity normalization (each voxel's mean was set to 100).

Statistical Analyses

We estimated several general linear models (GLMs) of the blood oxygenation level-dependent responses. All of the models allowed for first-order autoregression and included 6 motion parameters, constants, and linear time trends for each run as regressors-of-non-interest. A 2-stage mixed-effects analysis was performed in which the regression coefficients for each condition of interest were tested across participants via *t* tests. Two-tailed tests were used for all analyses.

We performed multiple comparison corrections at the cluster level using Monte Carlo simulations with the AlphaSim program (http://afni.nimh.nih.gov). Statistical inferences at the whole-brain level were carried out at a corrected threshold of $P < .05$ by imposing a $P < .005$ statistical threshold and a minimum cluster extent of 48 voxels. For predetermined regions of interest, we performed small volume corrections at the cluster level ($P < .005$ and extent threshold of 14 voxels for vmPFC). Activation coordinates are reported using Talairach coordinates.

We estimated the GLM on fMRI time-series data to identify brain regions that are systematically varied by our commercial stimuli and food decision choice trials. The statistical model included the following regressors: (1) food commercial event (15 seconds); (2) food choice trials of the food commercial block (with a duration from food stimulus onset to the decision time); (3) nonfood commercial event (15 seconds); (4) food choice trials of the non-food commercial block (with a duration from food stimulus onset to the decision time); (5) no commercial event (blank screen) (15 seconds); and (6) food choice trials of the no commercial block (with a duration from food stimulus onset to the decision time). The GLM also included block cues and missed trials as regressors of non-interest. All events were convolved with a canonical hemodynamic response function.

We carried out an independent regions of interest (ROI) analysis to further investigate how the vmPFC activity at the time of children's food choices is modulated by previous exposure to food commercials compared with nonfood commercials. The analysis involved the following steps. First, the vmPFC ROI was defined from the group-level contrast for the commercial film (food and nonfood combined) vs no commercial periods (blank). We expected that children would have positive experiences while watching the commercial compared with no commercial period, which would activate the brain reward circuitry including the vmPFC. Note that this contrast was independent of the decision events we were specifically testing (ie, no overlap). Second, for every subject we computed an average response measure by averaging the estimated individual voxel coefficients within the ROI (6-mm sphere from the peak; x = 5, y = 47, z = −7) for a particular contrast of interest. Third, the group level inference was made by performing a *t* test at $P < .05$ (2-sided).

Results

Behavioral Results

We examined whether watching food or nonfood commercials would change overall decision values of the food items. Food decision values acquired during the fMRI food decision task were coded using a 4-point scale (1: strong no, 2: no, 3: yes, and 4: strong yes). First, a 1-way repeated measures ANOVA on the mean food decision values was not significant ($F[2,44] = .39$, $P = .68$, $\eta^2 = .03$). We speculated that such short (15-second) food commercials might not be strong enough to make immediate decision changes in our experimental paradigm, but it could systematically change the way children make food choices overall.

Next, we predicted that across all conditions, children generally would make their food decisions primarily by the use of taste attribute values rather than incorporating health attribute values, and children would more heavily rely on taste attribute values for their food choices after watching food commercials. To test our behavioral hypotheses for taste and health attributes, we fitted a linear regression model of taste and health ratings on children's decisions separately for each commercial condition. Then, we performed *t* tests with estimated regression coefficients for group-level analyses. As shown in **Figure 2**, A, children's taste ratings significantly predicted food decisions for all 3 conditions (mean $\beta_{food} = .68$, $t[20] = 14.64$, $P < .001$; mean $\beta_{non\text{-}food} = .63$, $t[20] = 11.73$, $P < .001$; mean $\beta_{blank} = .66$, $t[20] = 12.44$, $P < .001$), and health ratings did not (mean $\beta_{food} = .01$, $t[20] = .38$, $P = .71$; mean $\beta_{non\text{-}food} = .03$, $t[20] = .77$, $P = .45$; mean $\beta_{blank} = .04$, $t[20] = 1.12$, $P = .28$). This implies that the health benefits of the children's food choices were secondary to taste when making their food choices.

To compare the effect of food vs nonfood commercials on decisions involving taste information, we performed a planned, paired *t* test on regression beta coefficients of taste attributes between the 2 commercial conditions. Interestingly, the decision weight of taste value was significantly increased after the children watched food commercial films (CF) compared with nonfood CF ($t[20] = 2.22$, $P < .05$), suggesting that the children's food decision process shifted towards valuing the tastiness of foods more highly after watching television food commercials. Subsequently, in a similar way, we compared the decision time between 2 CF conditions (**Figure 2**, B). Because of large variability of children's reaction time data, we analyzed each child's median to minimize the effects of outliers. Again, a paired *t* test result showed that children made food choices faster after watching food CF compared with nonfood CF (mean$_{food}$ = 1232 ms [SD = 262], mean$_{non\text{-}food}$ = 1273 ms [SD = 257]; $t[22] = -2.28$, $P < .05$).

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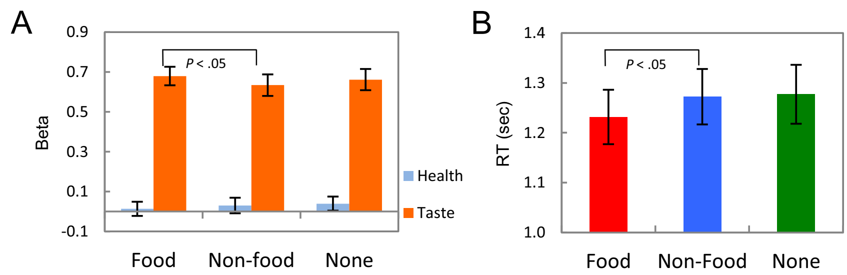

Figure 2. **A,** Child participants' food choices were solely predicted by taste ratings (all $P < .001$). In all conditions, health ratings were not significant (all $P > .05$). The influence of tastiness on children's food choices was increased significantly after watching food commercials compared with nonfood commercials. **B,** Child participants made food decisions quicker after watching food commercials compared with nonfood commercials. To reduce effects of outliers, median reaction times were calculated for each individual. All error bars denote SE.

fMRI Results

We examined fMRI data to explore how children's brain responded to 3 different commercial conditions (Table II). A comparison between food commercial and no commercial conditions showed broad brain activations including the vmPFC regions in brain reward circuits as well as sensory regions ($P < .05$ corrected; Figure 3, A [available at www.jpeds.com]). In our whole-brain analysis ($P < .05$ corrected), however, we did not observe any significant differences between food and non-food commercial presentations except for the right fusiform gyrus.

Next, we compared the decision trials of 3 commercial conditions. Consistent with our hypothesis, the vmPFC activity at the time of children's food choices was significantly increased after they watched food commercials compared with nonfood commercials ($P < .05$ corrected; Figure 3, B).

Table II. Brain regions in response to commercials and in response to choices

	L/R	Talairach x	y	z	t
Brain region response during commercial					
Food CF > No CF					
vmPFC	L/R	5	44	−10	4.51
Parahippocampal gyrus/amygdala	L	−31	−16	−7	5.09
	R	23	−7	−10	5.82
Superior temporal gyrus	L	−58	−12	5	7.38
	R	44	−28	8	6.88
Occipital gyrus/fusiform gyrus	L	−46	−70	−4	10.43
	R	38	−40	−16	11.07
Nonfood CF > No CF					
Superior temporal gyrus	L	−52	−25	5	6.34
	R	62	−13	2	8.15
Occipital gyrus/fusiform gyrus	L	−40	−49	−19	7.16
	R	14	−91	−13	7.31
Precuneus	L	−4	−73	44	−4.97
	R	17	−67	32	−6.26
Food CF > Nonfood CF					
Fusiform gyrus	R	17	−71	−11	4.11
Brain region response at time of choice					
Choices: food CF > nonfood CF					
vmPFC	L/R	5	44	−4	4.23[svc]

L, left; *R*, right.
svc, $P < .05$ with small volume correction (height threshold $t = 3.12$, $P < .005$; extent threshold k = 48 voxels; $k = 14$ voxels for vmPFC).

Considering that identical food images were shown across all commercial conditions, our results suggest that the vmPFC activity reflects changes in the decision process caused by the previous television food commercial exposure. No other region showed significant activations in whole-brain analyses, including the contrasts with the no commercials condition.

To further confirm the robustness of our whole-brain findings and correlational analyses, we performed additional ROI analyses. The vmPFC ROI was selected independently from the commercial period contrast. Then, the vmPFC activity was compared for the decision periods (Table II). As shown in Figure 4, A (available at www.jpeds.com), the vmPFC activity at the time of choices was significantly different depending on the type of commercials that children watched before their decisions ($t[22] = 2.90$, $P < .01$).

Finally, we explored whether the vmPFC activity differences are related to children's body weight status (assessed by the use of their calculated BMI percentile score) or motivational status (ie, self-reported hunger level). The commercial effect on the vmPFC activity was not significantly correlated with body mass ($r[21] = .08$, $P = .72$). Interestingly, however, the vmPFC activity differences positively correlated with the hunger level children reported just before fMRI scans ($r[21] = .47$, $P < .05$; Figure 4, A), implying that the neural commercial effect was larger when children were hungry. This correlation remained significant even after we controlled for liking and familiarity ratings for the commercials ($r_{partial}[16] = .52$, $P < .05$).

Discussion

From our behavioral results, we observed that children's ratings of a food item's taste predicted their choices. This finding is not surprising, given children's propensity toward choosing foods that are delicious, regardless of their health benefits. Previous studies have shown that taste is the primary predictor of product choice.[13] This reliance on the taste of the item was quite robust and occurred for those foods appearing after food commercials, nonfood commercials, and no commercial. The health ratings of the foods did not predict children's food choices, which contradicts previous findings from adults.[14,15] It seems that in contrast to adults, children place more emphasis on the taste when making decisions whether they wish to consume the food.

Watching food commercials increased the influence of the taste attribute further compared with nonfood commercials. That is, children favored specific items, and placed an even greater emphasis on taste attributes of these items, after watching the food commercials. This did not happen for the nonfood commercials.

Our results showed that watching food commercials changed the way children assess the importance of taste when making food choices. Children placed significantly more importance on taste after watching food commercials compared with nonfood commercials. It is possible that the food commercials prime children to focus on the more hedonic aspects of food. Food commercials may prompt children to consider their liking and wanting of specific food items, irrespective of the lack of any health benefits. This increased emphasis on taste may make it even more difficult for relevant caregivers to encourage healthy food choices. This evidence has implications for policies related to food advertising to children.

We also compared the time it took children to make a decision on foods after food commercials compared with after nonfood commercials. Overall, these results suggest that viewing food commercials may increase the propensity for children to make faster, more impulsive decisions.

The vmPFC, a brain region known to be associated with reward and value assessment,[16] showed increased activity at the time of food choice after watching food commercials compared with nonfood commercials. That is, food commercials increased brain activity in the specific brain region focused on encoding value. This shows that food commercials stimulate children's brains in a way that nonfood commercials do not. When we examined self-reported hunger levels in conjunction with the effects of the food commercials, the results were striking: the more hunger the child reported, the greater the vmPFC activity. These results suggest that when children are hungry, the effect of food commercials on brain activity may be particularly pronounced.

There are several limitations to the current study. First, our sample size was moderate, and future studies should use larger groups of youths and perhaps examine the effects of age on food decisions. Some of the nonfood commercials we used were for products that may be less relevant to children (ie, Allstate). Also, it would be worthwhile to study brain activity differences between lean children and overweight or obese children when making food decisions after watching commercials. Although the current design precludes an examination, future studies should make a distinction between healthy and unhealthy food choices. Overall, our results suggest food marketing can systematically bias psychological and neurobiological mechanisms of children's food decisions. ■

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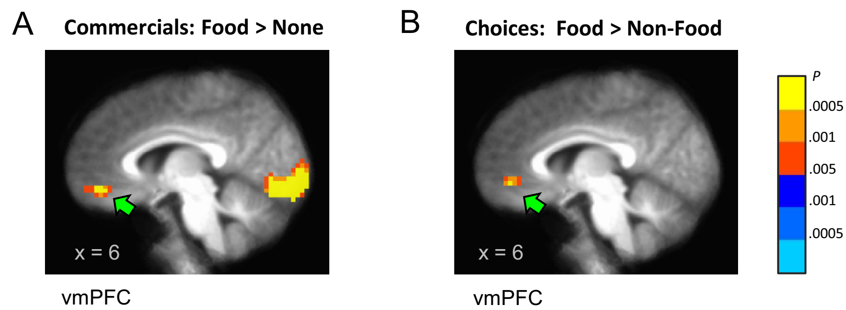

Figure 3. **A,** vmPFC showed stronger activity when participants watched food commercials compared with none condition (baseline). **B,** vmPFC showed stronger activity at the time of food choice after food commercials compared with nonfood commercials. All images were thresholded at $P < .05$ corrected.

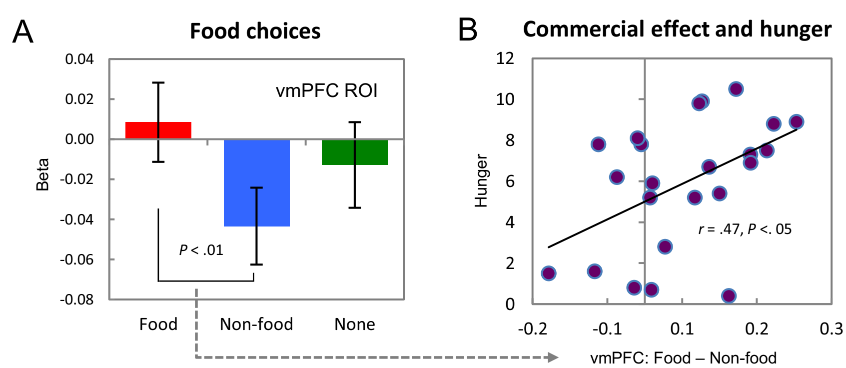

Figure 4. **A,** ROI plot. vmPFC ROI was selected independently from the commercials (food, nonfood) vs none contrast (a 6-mm sphere from the peak, x = 5, y = 47, z = –7). **B,** The commercial effect (food commercial – nonfood commercial) at the time of decision was associated positively with the hunger level that participants reported before the scanning. All error bars denote SE.