

Interactive effects of reward sensitivity and residential fast-food restaurant exposure on fast-food consumption^{1–3}

Catherine Paquet, Mark Daniel, Bärbel Knäuper, Lise Gauvin, Yan Kestens, and Laurette Dubé

ABSTRACT

Background: Local fast-food environments have been increasingly linked to obesity and related outcomes. Individuals who are more sensitive to reward-related cues might be more responsive to such environments.

Objective: This study aimed to assess the moderating role of sensitivity to reward on the relation between residential fast-food restaurant exposure and fast-food consumption.

Design: Four hundred fifteen individuals (49.6% men; mean age: 34.7 y) were sampled from 7 Montreal census tracts stratified by socioeconomic status and French/English language. The frequency of fast-food restaurant visits in the previous week was self-reported. Sensitivity to reward was self-reported by using the Behavioral Activation System (BAS) scale. Fast-food restaurant exposure within 500 m of the participants' residence was determined by using a Geographic Information System. Main and interactive effects of the BAS and fast-food restaurant exposure on fast-food consumption were tested with logistic regression models that accounted for clustering of observations and participants' age, sex, education, and household income.

Results: Regression results showed a significant interaction between BAS and fast-food restaurant exposure ($P < 0.001$). Analysis of BAS tertiles indicated that the association between neighborhood fast-food restaurant exposure and consumption was positive for the highest tertile (odds ratio: 1.49; 95% CI: 1.20, 1.84; $P < 0.001$) but null for the intermediate (odds ratio: 1.03; 95% CI: 0.80, 1.34; $P = 0.81$) and lowest (odds ratio: 0.84; 95% CI: 0.51, 1.37; $P = 0.49$) tertiles.

Conclusion: Reward-sensitive individuals may be more responsive to unhealthy cues in their immediate environment. *Am J Clin Nutr* 2010;91:771–6.

INTRODUCTION

Cues associated with palatable food are strong drivers of food consumption, even beyond homeostatic needs (1). The preponderance of such cues in our modern environment is considered to be a major contributor to the current obesity epidemic. However, not all individuals exposed to obesogenic environments will necessarily become obese. Various factors might influence individual responsiveness to environmental food cues. The need to identify such differences for explaining variations in individual resistance and susceptibility to weight gain (2) and obesity (3) is increasingly recognized. In addition, understanding for whom or under what circumstances the food environment is more likely to lead to overconsumption might assist the development and

implementation of tailored environmental interventions to fight obesity.

Recent advances in neuroscience could help in identifying individual characteristics that capture a propensity to respond to palatable food cues. Palatable foods such as those high in sugar and fat are highly reinforcing. The reinforcing effect of food is tied to reward brain pathways (4, 5), mediated in part by the dopaminergic systems (6, 7). Cues associated with palatable foods are known to activate such systems (4, 5, 8) and, in turn, to promote food intake (7). Important individual differences have been reported in these neural responses to food cues (9), thus highlighting potential individual variations in sensitivity to the reward properties of food.

Individual differences in responsiveness to incentive-related environmental cues are supported by studies measuring trait reward sensitivity using, for example, the Behavioral Activation System (BAS) scale. Measures of BAS have been shown to covary with differences in neural responses to food cues (9) and

¹ From the School of Health Sciences, University of South Australia, Adelaide, Australia (CP and MD); the Department of Medicine, St Vincent's Hospital, The University of Melbourne, Melbourne, Australia (MD); the Psychology Department, McGill University, Montreal, Canada (BK); the Département de Médecine Sociale et Préventive, Université de Montréal, Montreal, Canada; Centre de Recherche du Centre Hospitalier de l'Université de Montréal, Montreal, Canada (LG and YK); the Direction de Santé Publique de Montréal, Montreal, Canada (YK); and the Faculty of Management, McGill University, Montreal, Canada (LD).

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³ Address correspondence to C Paquet, School of Health Sciences, University of South Australia, City East Campus, GPO Box 2471, Adelaide, South Australia 5001, Australia. E-mail: catherine.paquet@unisa.edu.au.

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reflect a tendency for individuals to experience positive affect in response to incentives or appetitive stimuli and to engage in approach behaviors to attain these stimuli. Reward sensitivity has been positively associated with caloric consumption (10, 11), preference for sweet/fat food (10), obesity, and dysfunctional eating (12, 13). It was also found to discriminate individual responses when exposed to either rewarding (ie, varied) or monotonous food in a laboratory setting (14), which suggests that, in this study, reward sensitivity moderated responses to the manipulated food environment.

On the basis of this previous research, it was proposed that individual differences in reward sensitivity should be evaluated to understand variations in the influence of palatable food cues on health behaviors and related outcomes in the current obesogenic environment. The main effect of the accessibility or availability of fast-food restaurants (as measures of exposure to palatable but unhealthful food cues) on diet quality and obesity-related outcomes has been the object of many studies. Such studies have provided mixed support for a significant association. For instance, some studies have shown that a lower access to fast-food restaurants is associated with healthier diets and lower rates of obesity (15–17), whereas others (18–22) failed to support such relations. Limited research has addressed individual factors that could explain variations in the association between obesogenic environmental cues, such as cues potentially triggering intake of high-sugar and/or high-fat foods, and health outcomes. In particular, there is a need for population-based studies that evaluate the moderating role of psychological factors, such as reward sensitivity. This study sought to assess in a representative sample of urban-dwelling residents the moderating role of sensitivity to reward measured with the BAS scale on the association between residential exposure to fast-food restaurants, which are known to present extensive cues for high-fat, high-sugar foods (23), and fast-food consumption.

SUBJECTS AND METHODS

Context

This study derives from the Montreal Neighborhood Survey of Lifestyle and Health, which was designed to collect behavioral, psychosocial, and biological markers of health status and to integrate these into a Geographic Information System (24). The study used a stratified cluster sampling, where Montreal Island census tracts ($n = 521$) were stratified into tertiles of socioeconomic status (SES) based on census income and education data (25). Using 2001 Canada Census data, for each SES tertile, one dominantly French-speaking and one dominantly English-speaking census tract were randomly selected to represent both official Canadian languages. The resulting 6 census tracts were subsequently complemented with an additional medium-SES French tract to augment sample size.

Recruiters delivered informational material to noncommercial addresses within each census tract. Recruiters visited addresses 48–72 h after the delivery of material to inquire about willingness to participate in the study. Contact could not be established with residents of $\approx 40\%$ of addresses. Of those reached and eligible, $\approx 15\%$ agreed to participate. Inclusion criteria were as follows: aged between 18 and 55 y, no diagnosis of cardiovascular or metabolic disease, and ability to read French or English. A total

of 415 individuals participated in the study. For the present study, complete data were obtained for 404 participants (7 individuals were excluded because of missing BAS measures and 4 because of missing age values).

Data collection

Participants completed a questionnaire on health behaviors and psychosocial factors relevant to cardiovascular health by telephone, Internet, or hard copy mailers. Data were collected from March 2006 to April 2007. The participants' addresses were geocoded and integrated into a Geographic Information System (24) containing, among other databases, census data (25) and a comprehensive inventory of businesses and services (26) located within the Montreal Census Metropolitan Area (CMA) in 2005. The study was conducted in accordance with the ethical standards stated in the Canadian Tri-Council Policy Statement and were approved by the ethics committee of the Centre de Recherche du Centre Hospitalier de l'Université de Montréal.

Measures

Fast-food consumption was measured by using a 4-point scale, where individuals reported the number of times they had visited a fast-food restaurant in their neighborhood in the previous 7 d (0, 1–2, 3–4, or ≥ 5 times). Neighborhood was not a priori defined to allow participants to use their own definition of neighborhood. Given the high percentage of participants who had not been to a fast-food restaurant in that period (71%), responses were dichotomized in terms of one or more visits or no visits.

Reward sensitivity was measured by using the BAS component (thirteen 5-point items) of the Behavioral Inhibition System/BAS scales developed by Carver and White (27), a well-established measure that taps individual differences in the BAS (27). Items on the BAS scale pertain to persistence at pursuing goals, seeking new and pleasing stimuli, and anticipation of rewarding event. The scale includes items such as "When I see an opportunity for something I like, I get excited right away," "When I want something, I usually go 'all-out' to get it," and "I will often do things for no reason other than that they might be fun." The convergence and discriminant validity as well as the internal consistency of the scale have been demonstrated (27, 28). Items were summed to obtain an overall BAS score (scale: 0–65) for which the predictive ability in the domain of food was previously shown (10). Internal consistency among items was determined for the present study and was found adequate (Cronbach's $\alpha = 0.81$).

Fast-food restaurant exposure was operationalized as the number of fast-food restaurants located within 500 m of the participants' residence. Restaurants were extracted by using Standard Industry Classification codes from a commercial database (26) containing a comprehensive inventory of businesses and services located within the Montreal CMA in 2005. All businesses and services were geocoded by using GeoPinPoint software (version 6.4; DMTI Spatial Inc, Markham, Canada) either at the address (82%) or the 6-digit postal code (18%) level. Six-digit Canadian postal codes pertain to one side of one street section. A validation study of this commercial database in the Montreal CMA showed that it was valid in terms of the likelihood that a listed establishment was present in the field (positive predictive value = 0.90) and that a food establishment present in

the field was correctly listed in the database (sensitivity = 0.84) (29). Restaurants were coded as fast-food or non-fast-food by a rater with extensive knowledge of the Montreal restaurant industry. Fast-food restaurants were defined as any chain or nonchain restaurant offering rapidly prepared and served, primarily high-caloric food, for home or out-of-home consumption and were coded based on restaurant names only (30). Intrarater reliability was 90.2% when fast-food restaurants were recoded again, 3 mo later. Interrater reliability for classifications of fast-food restaurants by the same coder was also high ($\kappa = 0.73$) when previously assessed for the 2003 version of the database (30).

Covariates included the participants' age, sex, education, and household income. In a secondary analysis, we also accounted for area-level SES, given its reported inverse relation with the density of fast-food outlets (30–36). The participants self-reported their date of birth, educational attainment (9 categories), and household income (9 categories). Educational attainment was operationalized as being a university graduate or not and household income as low [$<20,000$ Canadian dollars (CAD)], medium (CAD 20,000–50,000), or high (more than CAD 50,000). We also accounted for the socioeconomic background within the participants' immediate residential environment by considering the proportion of households spending $\geq 20\%$ on food, shelter, and clothing than the average of households of similar size, region, and resident density (25). This variable was obtained at the census tract level by using 2001 census data and defined for a buffer zone of 500-m radii centered on the participant's residence by using the weighted average of values from any adjacent census tracts, with weights being defined by the proportion of the area of the buffer represented by each census tract.

Statistical analysis

Logistic regression analyses were conducted to test the main and interactive effects of BAS and fast-food restaurant exposure on fast-food consumption, with adjustment for age, sex, individual-level education and income, and residential SES (secondary analysis). Generalized estimating equations estimators were used to account for the clustering of observations within census tracts. All analyses were conducted by using SAS version 9.1.3 (SAS Institute, Cary, NC). Continuous predictors were standardized. Statistical significance was set at $\alpha = 0.05$.

RESULTS

Characteristics of the sample analyzed appear in **Table 1**. Two-sided exact binomial probability tests comparing characteristics of participants with Canada Census data (2001) for each selected census tract showed a greater proportion of participants holding a bachelor's degree than the general population of Montreal. In 3 census tracts, greater proportions of married and households with income greater than CAD 100,000 participants were found. One hundred eighteen participants had visited a fast-food restaurant in their neighborhood in the previous week. Results from the generalized estimating equations logistic regression analysis are reported in **Table 2** (model 1). The association between fast-food restaurant exposure and fast-food consumption was not statistically significant, whereas the BAS was positively associated with fast-food consumption. The BAS interacted significantly with fast-food restaurant exposure, with

TABLE 1

Descriptive information for participants in the Montreal Neighborhood Survey of Lifestyle and Health: 2006–2007 ($n = 404$)

Variable	No. of subjects	Mean \pm SD ¹
Sex		
Male (%)	198	49.0 \pm 2.5
Household income (%)		
Low: $< \$20,000/y$	150	37.1 \pm 2.4
Medium: $\$20,000–\$49,999/y$	127	31.4 \pm 2.3
High: $\geq \$50,000/y$	127	31.4 \pm 2.3
Education (%)		
No university degree	214	53.0 \pm 2.5
University degree	190	47.0 \pm 2.5
Primary household language (%)		
French	279	69.1 \pm 2.3
English	59	14.6 \pm 1.8
Other	66	16.3 \pm 1.8
Marital status (%)		
Married/common law union	190	47.0 \pm 2.5
Single	176	43.6 \pm 2.5
Widowed, separated, divorced	38	9.4 \pm 1.4
Proportion of low-income households	404	0.42 \pm 0.14
Age (y)	404	34.7 \pm 8.7
Behavioral Activation System scale, range 0–65	404	48.1 \pm 6.5
Fast-food restaurant exposure, range 0–9 (count per 500-m buffer)	404	2.9 \pm 2.6
Fast-food consumption in previous week (%)		
Not even once	286	70.8 \pm 2.3
At least once	118	29.2 \pm 2.3

¹ SD for proportions calculated by using WinPepi software version 6.9 (JH Abramson, Jerusalem, Israel).

the positive association between fast-food restaurant exposure and fast-food consumption being stronger among persons with higher BAS scores. None of the covariates were statistically significant in relation to fast-food consumption.

To explore the nature of the interaction between BAS and fast-food restaurant exposure, we estimated the association between fast-food restaurant exposure and fast-food consumption for different levels of BAS. To do so, the sample was divided into tertiles of BAS. Compared with individuals in the first 2 tertiles, individuals in the highest BAS tertile were younger [aged 33.0 (high BAS) compared with 35.6 (low-intermediate BAS) y; $P = 0.01$] and were less likely to be male [40.0% (high BAS) compared with 53.8% (low-intermediate BAS); $P = 0.02$] and to have a university degree [39.1% (high BAS) compared with 50.6% (low-intermediate BAS); $P = 0.04$] and a high income [$> \$50,000$; 22.6% (high BAS) compared with 35.2% (low-intermediate BAS); $P = 0.02$]. Results from analyses performed for each BAS tertile are illustrated in **Figure 1**, where the predicted log odds of having consumed fast-food in the past 7 d is plotted for different values of fast-food restaurant exposure (mean and 1 SD above and 1 SD below the mean) for all 3 tertiles of BAS. As illustrated, the association between neighborhood fast-food restaurant exposure and consumption was positive for the highest tertile (odds ratio: 1.49; 95% CI: 1.20, 1.84; $P < 0.001$), but null for the intermediate (odds ratio: 1.03; 95% CI: 0.80, 1.34; $P = 0.81$) and lowest (odds ratio: 0.84; 95% CI: 0.51, 1.37; $P = 0.49$) tertiles. For high-BAS individuals, an increase of 1 SD in fast-food restaurants was associated with

TABLE 2

Logistic regression results for the associations between fast-food consumption, Behavioral Activation System (BAS) scale, and fast-food restaurant exposure (main and interactive effects) accounting for covariates among participants in the Montreal Neighborhood Survey of Lifestyle and Health ($n = 404$)

Variable	Model 1				Model 2			
	Estimate	Odds ratio	95% CI	<i>P</i>	Estimate	Odds ratio	95% CI	<i>P</i>
BAS	0.194	1.21	1.05, 1.40	0.009	0.199	1.22	1.04, 1.43	0.01
Fast-food restaurant exposure	-0.085	0.92	0.80, 1.05	0.22	0.008	1.01	0.89, 1.14	0.89
BAS × fast-food restaurant exposure	0.201	1.22	1.09, 1.37	<0.001	0.199	1.22	1.08, 1.38	0.001
Age	-0.002	1.00	0.98, 1.02	0.85	-0.001	0.99	0.98, 1.02	0.95
Male	0.238	1.27	0.60, 2.66	0.53	0.195	1.22	0.56, 2.62	0.62
Low income: <\$20,000/y (referent)	—	—	—	—	—	—	—	—
Medium income: \$20,000–\$49,999/y	-0.117	0.89	0.55, 1.43	0.63	-0.090	0.91	0.57, 1.47	0.71
High income: ≥\$50,000/y	-0.031	0.97	0.58, 1.62	0.91	0.052	1.05	0.64, 1.72	0.84
At least one university degree	-0.484	0.62	0.35, 1.09	0.10	-0.449	0.64	0.35, 1.14	0.13
Proportion of low-income households in proximity to person's residence	—	—	—	—	0.189	1.21	0.94, 1.55	0.14

a 49% greater likelihood of having visited a fast-food restaurant in the previous week.

A secondary analysis was conducted on the basis of evidence that fast-food restaurants are more commonly found in deprived neighborhoods than in affluent neighborhoods (31, 33, 35, 36). Hence, our results might not be specific to fast-food restaurant exposure, but rather to the socioeconomic characteristics of the participants' immediate environment. To rule out this alternate explanation, we repeated the logistic regression analysis testing the main and interactive effects of BAS and fast-food restaurant exposure in association with fast-food consumption while accounting for the proportion of individuals under a low-income cutoff within 500 m of the participants' residence (Table 2, model 2). The main effect of BAS and its interaction with fast-food restaurant exposure remained statistically significant. The proportion of low-income individuals living in proximity to participants was not statistically significantly associated with fast-food consumption.

DISCUSSION

The results of the present study indicate that the association between exposure to fast-food restaurants and fast-food consumption varies with an individual's predisposition to engage in rewarding behaviors. This study provides initial evidence for the moderating influence of reward sensitivity in a natural setting with a population-based sample. The results echo laboratory findings showing that a palatability manipulation was found to be effective only in participants who were highly sensitive to reward (14). The present study extends previous laboratory work by showing that such associations hold in a real-world setting.

Significant research efforts are underway to evaluate the importance of the food environment in shaping dietary behaviors that contribute to current obesity rates. The available evidence is mixed. Hence, there is a need for more refined hypotheses to evaluate under what circumstances or for whom environmental factors may influence energy balance-related behaviors (37–39) and obesity-related outcomes (40). Despite the recognition that individual factors are likely to play a role in moderating environmental influences on health and health behaviors, studies

explicitly focusing on this issue have been scarce. Research investigating individual-level moderators of the association between the fast-food environment and health behaviors and outcomes have focused mainly on individual or area-level sociodemographic factors such as age, sex, education, income, and ethnicity (15, 18, 19, 21, 22). In these studies, none of these sociodemographic factors were found to statistically moderate the association between exposure to fast-food restaurant and behavioral/obesity outcomes.

Moving beyond sociodemographic moderating factors, the present study assessed and provides evidence for the moderating influence of psychological factors on the relation between the food environment and health-related behavior. Future studies are needed to explore the moderating role of other psychological constructs. Of particular relevance in the current obesogenic context is the ability of individuals to execute control over their impulses. Beyond the homeostatic regulation of eating, 2 brain

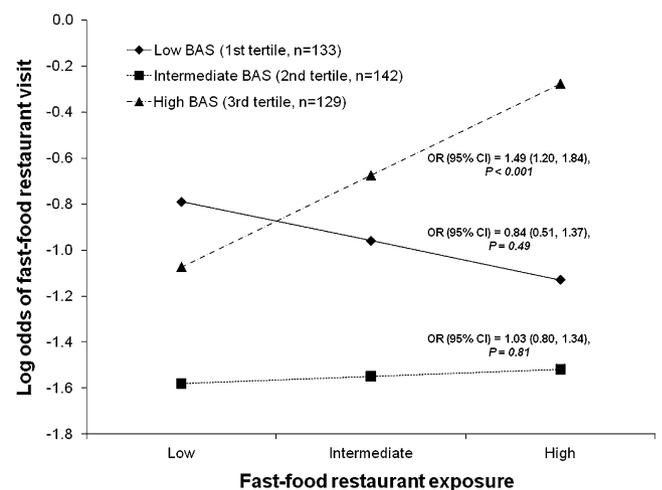


FIGURE 1. Predicted log odds ratios (ORs) of having visited a local fast-food restaurant at low (1 SD below the mean), intermediate (mean), and high (1 SD above the mean) levels of fast-food restaurant exposure for tertiles of the Behavioral Activation System (BAS) scale from logistic regression analyses with values estimated for average-aged, middle-income men with a university education.

systems appear to be important in the regulation of eating behavior. The present study examined one of these systems, namely the striatal-dopaminergic reward brain system, which underlies responsiveness to incentive-related environmental cues. The second system represents the cognitive processes involving the prefrontal cortex, which can inhibit cue-induced responses when these have negative consequences (41, 42). Future research is needed to assess whether or not individual differences in inhibitory processes could also explain which individuals are more likely to respond to the current obesogenic food environment. Studies could also evaluate the moderating role of food-specific reward sensitivity as assessed by the newly developed power of food scale (43), which was developed specifically to represent individual differences in the psychological effect of living in food-abundant environments.

By identifying individual factors contributing to susceptibility to environmental influences, this study is relevant to 1) determining priorities for implementing environmental interventions by prioritizing groups of individuals who would be most likely to benefit from such interventions, and 2) developing broadly-based public health mass media campaigns addressing both factors predisposing (eg, sensitivity to reward) and reinforcing (eg, fast-food exposure) unhealthy diets as well as their combined influence. Identification of individuals at risk could be achieved by using simple assessment tools such as the BAS or the aforementioned power of food scale. Susceptible individuals could also be identified by determining potential correlates of reward sensitivity. In our sample, high-BAS individuals tended to come from poorer socioeconomic backgrounds. If this observation is generalizable, it implies that individuals of low socioeconomic backgrounds are potentially more sensitive to fast-food cues, although the direction of this association remains to be determined. These individuals are also more likely to live in deprived neighborhoods, which could potentially compound their risk of overconsuming fast-food given accumulating evidence that the density of fast-food outlets is greater in relatively more deprived neighborhoods (31, 33, 35, 36).

Understanding which individuals are more susceptible to environmental food cues might also help tailor individual interventions addressing such vulnerabilities as either a complement or an alternative to environmental interventions. A recent study showed that the effectiveness of strategies to cope with food cravings depends on the psychological sensitivity to the food environment (44). Specifically, acceptance-based strategies, which entails recognizing and accepting (as opposed to controlling) one's thoughts and feelings about food, were found to be particularly effective in individuals who were considered more susceptible to the influence of food environment. Similar strategies could potentially be developed to help susceptible individuals coping with their tendency to respond to environmental food cues.

Limitations of this study include its cross-sectional design, which precludes inference regarding the direction of relations. In addition, fast-food consumption was based on a proxy measure using visits to a local fast-food restaurant in the previous week. Future studies could provide a more direct measure of eating habits as provided by food diaries and food-frequency questionnaires. Many studies investigating the health correlates of local fast-food environments have used a relative measure of exposure, such as the number of facilities per capita (45) or the

proportions of restaurants that serve primarily fast-food (15). In the present study, we opted for a more direct measure of exposure. Results from post hoc analyses using a relative measure of fast-food restaurant exposure (proportion of restaurants that are fast-food) did not largely differ from the ones presented above. In addition, the study context limits the generalizability of the results. Our investigation was limited to 7 census tracts on the Island of Montreal, selected to be representative of the Montreal population in terms of spectrum of socioeconomic level and language. These census tracts may not have been representative of the fast-food environment of the entire Island. The low response rate could also have influenced the generalizability of the results. The sample, however, did not largely differ from the base population, except in terms of education, which has already been associated with higher response rates (46). Future studies are required to assess whether or not the moderating role of reward sensitivity extends to biological markers of cardiometabolic risk, which have also been associated with the fast-food environment.

In conclusion, reward-sensitive individuals may be more responsive to unhealthy cues in their immediate environment than are individuals less sensitive to reward signals. Understanding these moderating factors can provide valuable insights into environmental influences on health-related outcomes in vulnerable populations (39) and also help direct resources to those most likely to benefit through tailored interventions based on such observations (47). Future research is needed to develop health promotion and public health strategies recognizing and addressing the sensitivity to environmental food reward cues for certain individuals residing in unhealthy food environments.

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