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Investigating an Incentive-Sensitization Model of Eating Behavior: Impact of a Simulated Fast-Food Laboratory

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Abstract

The incentive-sensitization (IS) theory proposes that "wanting" (strong motivation), more so than "liking" (hedonic pleasure), drives compulsive consumption in both substance use and overeating. Importantly, "wanting" and "liking" are only distinct in the presence of relevant cues. Cues may also contribute to overeating by increasing feelings of hunger. We employed a simulated fast-food laboratory to test IS theory by examining the effect of environmental cues on eating behavior. We tested the following hypotheses: In a cue-rich compared to neutral environment, (a) wanting would be greater whereas liking would remain the same, (b) feelings of hunger would be greater, and (c) food consumption would be greater, a relationship mediated by elevated wanting and hunger. These hypotheses were supported in the current study. Thus, contextual cues may contribute to overconsumption through increased wanting and hunger. These findings have public health implications for overeating and obesity.

Keywords

incentive sensitization, eating behavior, cues

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Similar mechanisms may contribute to both overeating and addictive behaviors. For example, consumption of both drugs of abuse and calorie-dense, nutrient-poor foods (e.g., cookies, cake) activates neuronal circuitry implicated in reward and motivation (Berridge, 2009; Volkow, Wang, Fowler, & Telang, 2008). Although there are important differences between food and drugs of abuse, namely that food is necessary for survival, overeating and substance use are associated with similar behavioral consequences, such as craving, withdrawal, and binging (Avena, Rada, & Hoebel, 2008; P. M. Johnson & Kenny, 2010). The incentive sensitization (IS) theory outlines potential shared mechanisms, proposing that compulsive consummatory behaviors are driven by "wanting" (i.e., a strong motivation to obtain and consume a substance; typically manifesting as craving or strong desire to use), rather than by "liking" (i.e., the hedonic pleasure derived from a substance; T. E. Robinson & Berridge, 2000). Initially, the target substance is often both wanted and liked (M. J. Robinson, Fischer, Ahuja, Lesser, & Maniates, 2015); however with continued exposure, "wanting" can occur even after "liking" is diminished (Berridge, 2009). With repeated consumption, the user becomes sensitized to substance-related cues (T. E. Robinson & Berridge, 2000), which begin to trigger dopaminergic release and increased "wanting" (Volkow, Wang, & Baler, 2011). In fact, T. E. Robinson and Berridge (2000) emphasize that evidence of IS is detectable only in the context of associated cues. Thus, it is important to test the predictions outlined by the IS theory regarding eating behavior in a cue-rich context.

Cues may also affect one's motivational drive to consume food by increasing feelings of hunger. Although hunger is usually interpreted as a homeostatic signal indicating caloric need, food is often consumed for other reasons, such as hedonic pleasure (Lowe & Butryn, 2007). Environmental cues can lead people to feel hungry even if they are in a state of satiety (Cohen, 2008; A. W. Johnson, 2013). For example, when exposed

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to pizza or ice cream, individuals who previously indicated they were full expressed increased desire to eat (Cornell, Rodin, & Weingarten, 1989). Although these feelings of hunger may be interpreted as caloric need, they may actually be occurring in response to environmental cues and may reflect increased motivational drive to acquire food. Furthermore, biological systems implicated in reward communicate with homeostatic systems involved in the experience of hunger (Volkow et al., 2011). When individuals are exposed to palatable food cues in a state of satiety, this can lead to increased levels of gut peptides that are implicated in the experience of hunger (i.e., orexin and ghrelin; Malik, McGlone, Bedrossian, & Dagher, 2008; Volkow et al., 2011). Thus, feelings of hunger (which are often interpreted as caloric need) can actually signal increased cue-induced "wanting" or motivation to consume food. Understanding how feelings of hunger are affected by the presence of cues may help people better interpret and respond to such feelings in cue-rich contexts. Furthermore, hunger state may also moderate the effect of cues. Generally, being in a state of hunger amplifies a cue's incentive salience (Berridge, Ho, Richard, & DiFeliceantonio, 2010). In a state of satiety, these effects may be dampened, with cues holding less motivational value. Thus, examining the interaction between hunger and the presence of cues will provide a better understanding of how hunger relates to food wanting.

Studies examining the effect of cues on eating behavior typically involve the sight or smell of the cued food (Boswell & Kober, 2016). Cue exposure in these paradigms has been associated with greater craving, consumption, hunger, and desire to eat (Fedoroff, Polivy, & Herman, 2003; Ferriday & Brunstrom, 2011; Tetley, Brunstrom, & Griffiths, 2010). However, little research has examined the effect of cues on both food wanting and food liking in the same study, which is necessary to thoroughly test IS. In studies that have, evidence for the separability of wanting and liking in human eating behavior has been mixed (Finlayson & Dalton, 2012; Havermans, 2011, 2012). One reason may be that the cue paradigms used in these studies are not sufficient to trigger the intense wanting postulated by the IS theory. In a recent review of liking and wanting measurement (Pool, Sennwald, Delplanque, Brosch, & Sander, 2016), 76% of the studies reviewed used a photo of the food as the cue. However, some studies employing the sight or smell of a cued food have been unable to find a main effect of cue exposure on eating behavior (Coelho, Jansen, Roefs, & Nederkoorn, 2009; Zoon, He, de Wijk, de Graaf, & Boesveldt, 2014). Although an image of the target food may be a sufficient cue to trigger wanting for some individuals, cues that trigger food wanting in everyday life likely include a combination of many elements in the environment where one consumes food. In a restaurant, for example, cues might include ambient music, the experience of being served by wait staff, and the furnishings of the dining room in addition to images, smells, and presentation of the food itself. Presenting a photo or the smell of the food alone does not address these contextual factors that may serve as additional cues. It is possible that a more naturalistic, cue-rich environment, which includes contextual factors in addition to food presentation, is necessary to observe the separability of liking and wanting in laboratory studies.

Research on alcohol use has set a precedent for the study of appetitive behaviors in a cue-rich environment. Simulated bar laboratories examine drinking behavior in an environment mimicking the setting in which people are likely to consume alcohol in their day-to-day life (Wall, Hinson, McKee, & Goldstein, 2001). Participants in these naturalistic settings report greater pleasurable subjective effects (e.g., greater stimulation, pleasurable disinhibition, sociability) from drinking compared to those in neutral settings (Wall et al., 2001), suggesting that the bar lab environment captures a more thorough range of factors that may contribute to problematic use. Although bar labs are an important setting in alcohol research, an equivalent in food research has not been employed to evaluate differences in liking and wanting, limiting our understanding of the ability of food-related environmental cues to trigger food-seeking behavior or a pleasurable hedonic experience. Furthermore, there have been no tests in either alcohol or food research of how liking and wanting may be differentially related to patterns of consumption in a cue-rich relative to neutral environment. Given that cues are central to triggering wanting and that current cue paradigms (e.g., images, smells) have had limited success in observing a distinction between liking and wanting, examining eating behavior in a cue-rich, naturalistic environment may be a more thorough way to test the tenets of IS theory.

Although food-related cues may have an influence on eating behavior, this influence may differ based on certain individual difference factors, such as eating pathology or gender. Individuals attempting to restrain their dietary intake may be more responsive to food cues and be more prone to consume greater amounts of a cued food than unrestrained eaters (Fedoroff et al., 2003). In addition, as the IS theory suggests, cues associated with a substance are more salient and more capable of enhancing motivation in individuals who are addicted to that substance (Franken, 2003; T. E. Robinson & Berridge, 2000). Thus, individuals with greater food addiction symptoms may be more responsive to an environment rich in food cues. Finally, women compared to men tend to have higher rates of eating pathology symptoms (e.g., binge eating, loss of control over eating; Lewinsohn, Seeley, Moerk, & Striegel-Moore, 2002), thus women may be more susceptible to the effects of a cue-rich environment on eating behavior.

The current study will use a cue-rich, simulated fast-food restaurant laboratory to test an IS model of eating behavior. Aim 1 is to investigate the separability of wanting and liking proposed by IS in the fast-food laboratory (cue-rich environment) relative to a neutral environment. Wanting will be operationalized using self-report and an established behavioral measure, the relative reinforcing value (RRV) task (Epstein, Leddy, Temple, & Faith, 2007; Temple, 2014). This task assesses how hard an individual will work to obtain a reward such as food. Liking will be operationalized using self-report measures assessing both taste-specific and general aspects of hedonic pleasure derived from foods. We hypothesize that a cue-rich environment will contribute to increased wanting, but not increased liking. Aim 2 is to investigate how self-reported hunger differs in the cue-rich environment relative to the neutral environment. We hypothesize that participants will report experiencing greater hunger in the cue-rich environment. Given that hunger state may affect the incentive salience of cues, we will also conduct exploratory analyses investigating whether hunger at baseline moderates the relationship between laboratory environment and food wanting, liking, and consumption. Aim 3 is to investigate differences in caloric consumption between the two conditions, as well as test mechanisms contributing to overeating by examining self-reported wanting and hunger as mediators in the relationship between laboratory environment and caloric consumption. We hypothesize that participants will consume more calories in the cue-rich environment and that food wanting and hunger will be significant mediators in this relationship. In addition, eating behavior may be influenced by gender or individual differences in eating pathology symptoms (e.g., restraint, food addiction). Thus, we conducted exploratory analyses examining whether gender or individual risk factors for overeating (e.g., restraint, food addiction symptoms) serve as moderators in the relationship between laboratory environment and food wanting, food liking, hunger, and consumption.

Method

Participants

Participants were undergraduate students who received course credit as compensation. Participants were ineligible if they had food allergies or dietary restrictions that prohibited them from consuming the foods used in the protocol. A total of 126 participants completed the study. Of them, 2 participants were excluded because of dietary restrictions they had not reported before participating in the study, 7 participants were excluded due to failing a validity check regarding their understanding of protocol instructions by answering one or more of three brief questions about study instructions incorrectly, and 5 participants were excluded for having outlying data (>2 *SD* above the mean) in variables of interest, leaving a final sample size of 112. Participants' mean age was 18.98 (*SD* = 1.24), and mean body mass index (BMI) was 23.66 (*SD* = 4.03). Weight status distribution was as follows; 4 (3.6%) participants were underweight, 74 (66.1%) were normal weight, 22 (19.6%) were overweight, and 10 (8.9%) were obese. In all, 64 (57.1%) participants were female, 47 (42.0%) were male, and 1 participant did not report gender. The racial breakdown was as follows: 84 (75.0%) White, 22 (19.6%) Asian, 4 (3.6%) Hispanic, 2 (1.8%) Black, 1 (0.9%) American Indian, and 2 (1.8%) other or more than one race. Participant demographic variables are presented in Table 1.

Procedure

The study was approved by the University of Michigan Health and Behavioral Sciences Institutional Review Board. Written informed consent was obtained from all participants. Participants were randomly assigned to either a naturalistic fast-food laboratory (cue-rich environment) or a neutral laboratory (neutral environment; see Table 1 for demographic and baseline characteristics of each group). To standardize hunger, participants were instructed to eat whatever constituted a typical lunch for them at least one hour prior to arriving for the study. Study sessions were all conducted between lunchtime and dinnertime. Upon participants' arrival in the lab, baseline ratings for self-reported food wanting and hunger were collected. Next, participants were taken to the randomly assigned environment. There, they engaged in the RRV task to earn tokens to be redeemed for foods typically available at a fast-food restaurant (e.g., cheeseburger, French fries, milkshake, non-diet soda) or for time to participate in an alternate activity (i.e., playing video games on a tablet). After completing the RRV task, participants again provided ratings for self-reported food wanting and hunger (post-RRV wanting and hunger). Next, participants redeemed their tokens for both fast food and time to play games (RRV food consumption period; calorie and weight information shown in Table S1 in the Supplemental Material available online). There is evidence that visually stimulating tasks such as playing video games can reduce food cravings (Skorka-Brown, Andrade, & May, 2014). To reduce this effect, participants were not allowed to consume food and play

Table 1. Demographic and Baseline Characteristics of the Sample

Variable	Total	Cue-rich	Neutral	*F* or χ^2	*p*	η^2 or φ
Gender (*n*, %)				0.15	.70	–.04
Male	47 (42.9)	26 (43.3)	21 (40.4)			
Female	64 (57.1)	33 (55.0)	31 (59.6)			
Race (*n*, %)				3.88	.57	.19
White	84 (75.0)	43 (71.7)	41 (78.8)			
Asian	22 (19.6)	11 (18.3)	11 (21.2)			
Hispanic	4 (3.6)	3 (5.0)	1 (1.9)			
Black	2 (1.8)	2 (3.3)	0			
American Indian	1 (0.9)	1 (1.7)	0			
Other/more than one race	2 (1.8)	1 (1.7)	1 (1.9)			
Age	18.98 (1.24)	19.02 (1.20)	18.94 (1.31)	0.10	.75	.00
BMI	23.66 (4.03)	23.94 (4.23)	23.35 (3.81)	0.60	.44	.01
Weight status (*n*, %)				1.48	.69	.12
Underweight	4 (3.6)	1 (1.7)	3 (5.8)			
Normal weight (*n*, %)	74 (66.1)	39 (65.0)	35 (67.3)			
Overweight (*n*, %)	22 (19.6)	12 (20.0)	10 (19.2)			
Obese (*n*, %)	10 (8.9)	6 (10.0)	4 (7.7)			
Baseline food wanting	2.92 (1.12)	3.02 (1.19)	2.81 (1.03)	0.98	.33	.01
Baseline game wanting	3.20 (1.38)	3.13 (1.43)	3.27 (1.33)	0.27	.61	.00
Baseline hunger	36.21 (19.44)	39.13 (19.16)	32.83 (19.40)	2.98	.09	.03
YFAS symptom count	1.72 (1.28)	1.80 (1.23)	1.61 (1.34)	0.59	.45	.01
TFEQ restraint	12.85 (3.33)	12.82 (3.03)	12.88 (3.68)	0.01	.93	.00

Note: Values are mean and standard deviation, unless otherwise noted. Chi-square test statistics (χ^2, φ) are presented for categorical variables (i.e., gender, race, weight status). One-way ANOVA test statistics (*F*, η^2) are presented for continuous variables. TFEQ = Three-Factor Eating Questionnaire; YFAS = Yale Food Addiction Scale.

games simultaneously. Instead, participants redeemed tokens and chose to either consume food or play games first, then began the second activity once they had finished engaging in the first. Participants were given the choice of which activity to engage in first.

Following the consumption periods, participants received ad libitum access to snack foods (e.g., Lay's potato chips, Cheez-Its, M&Ms, Skittles) and games for 10 min to assess the amount participants would eat when consumption was not limited by RRV performance (ad libitum consumption period; calorie and weight information shown in Table S2 in the Supplemental Material). Snack foods were provided instead of the fast-food items used in the RRV consumption period to minimize any effect of sensory-specific satiety (i.e., declining satisfaction due to intake of the same type or flavor of food) on consumption (Rolls, 1986). Next, participants were taken to a separate room where they completed a survey including self-reported liking for the foods consumed during the study and demographics. Finally, height and weight measurements were collected to calculate BMI (kg/m^2). These measurements were taken at the conclusion of the study to prevent any influence they might have on eating behavior. A flowchart illustrating the entire study procedure is shown in Figure 1.

Laboratory environment

The cue-rich environment was designed to simulate the experience of being in a fast-food restaurant. This environment included condiment and napkin holders, tables and accompanying chairs and booths, and had low background music playing. Menu boards with images of each food or game were projected on large television screens (see Figs. S1 and S2 in the Supplemental Material online). Participants ordered from a kitchen window through which industrial restaurant-style food storage and preparation appliances were visible. Research assistants who took orders from and served participants wore aprons and hats similar to those worn by fast-food employees. French fries were cooked in the kitchen immediately before participants arrived in the lab to simulate olfactory aspects of the fast-food experience. In the cue-rich environment, participants were served food on red plastic trays, and serving implements (e.g., paper sleeves for burgers and French fries, cups for soda and milkshakes) were chosen to resemble those seen in fast-food restaurants.

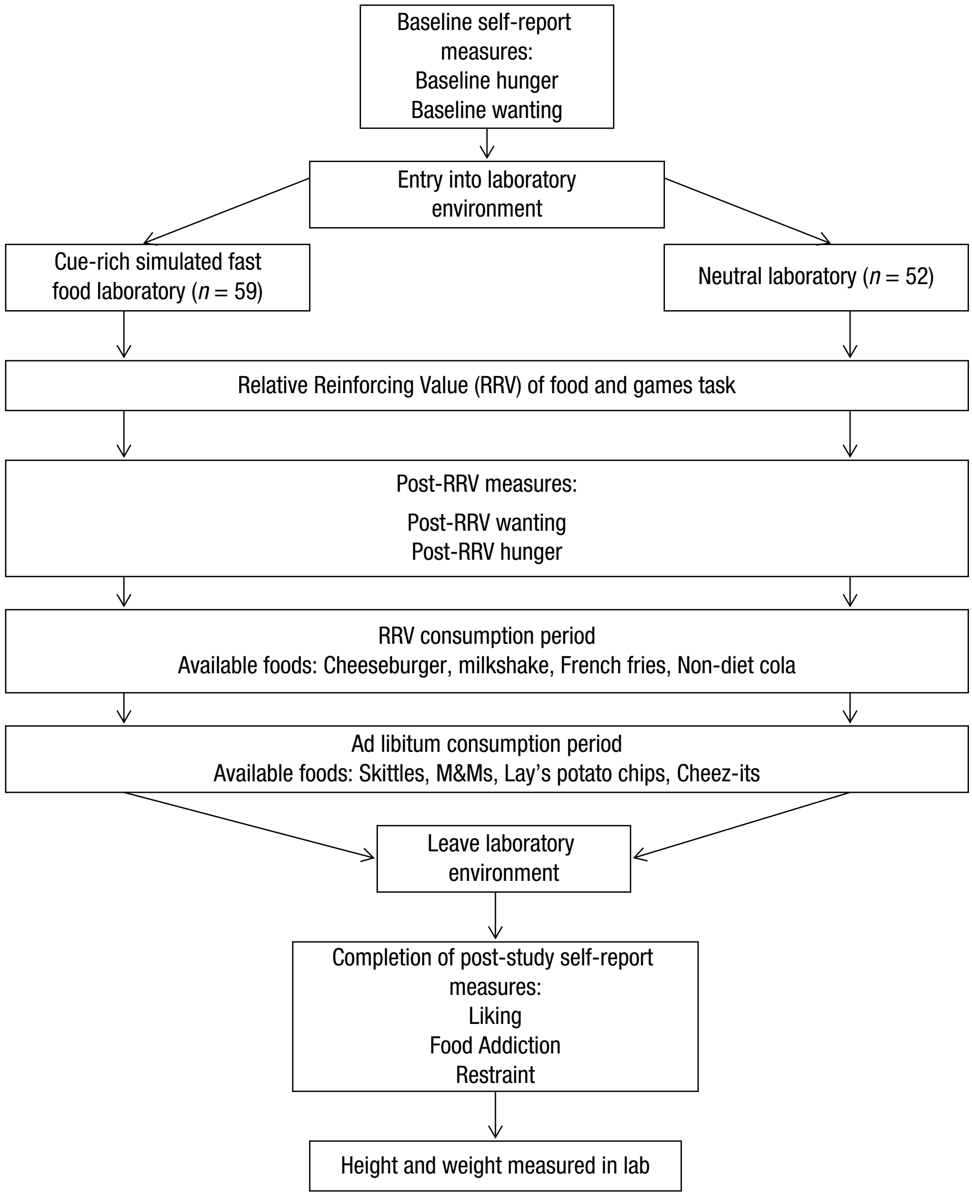

Fig. 1. Flowchart illustrating the procedure timeline.

The neutral environment was an office space in the research laboratory. In this environment, text-only menu boards were printed on laminated paper and hung on the wall. A research assistant dressed in street clothes came in to take participants' orders, and participants did not have a view of food preparation. No music was playing, and an air filter was used to ensure a neutral scent. Participants in the neutral environment were served food on clear plastic trays, and serving implements (e.g., paper plates and cups) were chosen to resemble those that one might buy for use at home.

Measures

Relative reinforcing value of food and games (food RRV, game RRV). As a behavioral measure of wanting, we used the RRV task (Epstein et al., 2007; Saelens & Epstein, 1996; Temple, 2014). In this task, participants respond with a number of button presses on a computer to earn points that can be used to obtain fast foods (e.g., cheeseburger, French fries, milkshake, and soda), and time playing video games on a tablet (e.g., Angry Birds, Temple Run, Solitaire, and Bejeweled). Games served as an alternate reinforcer to ensure that food RRV reflected motivation to work for food and that participants were not working for food out of boredom or lack of other options. Participants were allowed to move back and forth between stations as they wished and could continue the task to earn as many points as they wished. The task ended when the participant chose to stop playing for points.

The computer task consisted of a screen showing three different shapes, and each time the participant pressed the mouse button the shapes would change. When all three shapes matched, participants earned 1 point. For every 5 points, they received one token that could be used toward the relevant reinforcer once they were finished with the RRV task. Points were earned on a fixed ratio reinforcement schedule beginning at 50 button presses (FR50), and doubling each time they earned 5 points (i.e., FR100, FR200, FR400, FR800, FR1600, FR3200, FR6400, FR12800). Food and game RRV were determined by the highest fixed ratio schedule completed for each reinforcer. Upon completion of the RRV task, participants were given the opportunity to redeem their tokens for food and games.

Self-reported food and game wanting. To assess wanting for food and games, participants responded to the questions “How much do you WANT to eat food right now?” and “How much do you WANT to play games right now?” on a 1 to 6 scale ranging from *not at all* to *very much*. Both food and game wanting measurements were obtained once at baseline and once after the RRV task (post-RRV).

Food and game liking. Participants rated how much they liked the taste of each food they ate during the study on a 1 to 6 scale ranging from *not at all* to *very much*. This rating was averaged across all the foods eaten by the participant to obtain an overall liking rating. Participants were also asked to rate on the same scale how much they enjoyed the food they ate during the study to capture hedonic pleasure aspects nonspecific to taste. Eleven participants chose not to order any food during the RRV consumption period and thus are not included in liking analyses. Finally, participants rated on the same scale how much they enjoyed playing the games during the study. All liking measurements were obtained at the end of the study as part of the poststudy survey.

Hunger. To assess feelings of hunger, participants used a visual analog scale (VAS) to rate their hunger on a 0 to 100 scale ranging from *I am not hungry at all* to *I have never been more hungry*. Hunger was assessed once at baseline and once after the RRV task (post-RRV).

Food consumption. During the RRV food consumption period, participants traded their tokens obtained during the task for small or large portions of the fast foods of their choice (serving sizes and calorie information shown in Table S1 in the Supplemental Material). They also had access to packets of condiments commonly found in fast-food restaurants (i.e., mustard, ketchup, mayonnaise, salt, pepper). After participants ordered food following the RRV task, researchers prepared the food and weighed the food in grams before serving. Once the participant was finished eating, researchers weighed any remaining food. The post weight was subtracted from the pre weight to calculate the weight consumed. The weight of any condiments consumed was estimated based on the number of condiment packets used by the participant and the standard weight of each condiment packet. During the ad libitum consumption period, all participants had access to bowls containing standardized amounts (see Table S2 in the Supplemental Material) of four snack foods for 10 min. After this period, the bowls were weighed and the post weights were subtracted from the pre weights to calculate the weight of each snack food consumed. For both consumption periods, calories consumed were calculated based on the weight consumed and the calories per gram of each food item, obtained using the labeled nutrition facts of each food item. Calorie consumption was calculated based on the amount of food consumed following the RRV task and ad libitum consumption separately. Total calories consumed were calculated by adding together the RRV and ad libitum calories consumed by each participant.

Individual difference measures. The Three-Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985) assesses eating behaviors across three dimensions: cognitive restraint of eating, disinhibition, and hunger. The TFEQ has been shown to have excellent internal consistency and good test-retest reliability. The cognitive restraint subscale was used in the current study, and showed acceptable to internal consistency (α = .75). The mean TFEQ restraint score in the current sample was 12.85 (*SD* = 3.33)

The Yale Food Addiction Scale (YFAS; Gearhardt, Corbin, & Brownell, 2009) assesses symptoms of addiction toward certain types of foods (e.g., highly processed, high in fat, high in sugar) based on *DSM-IV-TR* (American Psychiatric Association, 2000) substance dependence criteria. The YFAS “symptom count” score ranges from 0 to 7 and reflects the number of addiction criteria endorsed. In the current sample, the YFAS showed good internal consistency (α = .85). The mean YFAS symptom count score in the current sample was 1.72 (*SD* = 1.28).

Data analytic plan

All analyses were conducted using IBM SPSS 22 (IBM, 2013). We first used frequencies to examine the distributions of all variables of interest. Two outliers (>2 *SD* above the mean) were found in the total calorie consumption variable, two outliers were found in the ad libitum calorie consumption variable, and one outlier was found in the game RRV variable. These cases were removed to normalize the distribution of these variables. We also found some individuals to be missing data for specific variables due to reasons such as errors in the survey program preventing that data from being saved properly or not completing portions of the study protocol.[1] These participants were excluded only from analyses involving those variables for which they were missing data. To assess for potential covariates, we conducted correlational analyses and one-way analysis of variance (ANOVA) to examine relationships between demographic variables (i.e.. race, age, gender, BMI) and the dependent variables (e.g., food RRV, post-RRV food wanting, postconsumption food liking, post-RRV hunger, RRV food consumption, and ad libitum food consumption). No significant associations were found (all *p*s >.05), thus these variables were not included as covariates. We conducted one-way ANOVAs and chi-square analyses to determine the success of random distribution of demographic variables into each condition. Demographic variables, baseline food and game wanting, and baseline hunger did not differ significantly by condition (all *p*s > .05; see Table 1 for group means).

To test Aim 1, we conducted one-way ANOVAs to examine whether food wanting and food liking differed between experimental conditions (i.e., cue-rich or neutral laboratory environment). To ensure that any differences in wanting and liking were specific to food, we also tested whether game wanting and game liking differed by condition.

To test Aim 2, we conducted one-way ANOVAs to test whether self-reported hunger differed between experimental conditions. We also examined interaction terms in separate multiple regression analyses to test whether baseline hunger moderated the relationship between laboratory environment and wanting and liking, as well as RRV, ad libitum, and total consumption.

To test Aim 3, we first conducted one-way ANOVAs to test whether food consumption (i.e., RRV, ad libitum, and total calories consumed) differed between conditions. Then we conducted mediation analyses using the PROCESS macro developed by Hayes (2012). Because participants' consumption during the RRV period was directly tied to their RRV performance (food RRV), we focused our mediational analyses on post-RRV self-report measures (i.e., food wanting, hunger) and used total consumption as the outcome. Variables that did not significantly differ by condition were not included in mediation models. To test the hypothesized mediation models (e.g., laboratory environment → post-RRV self-reported food wanting → total food consumption), we employed the bootstrapping method with 10,000 samples described by Preacher and Hayes (2008), which yields a 95% confidence interval (CI). The completely standardized indirect effect (ab_{cs}; Preacher & Kelley, 2011) was used to compare the effect sizes of statistically significant indirect effects. Effect sizes can be interpreted as small (.01), medium (.09), or large (.25; Kenny, 2014).

Finally, we conducted exploratory analyses to examine interaction terms in separate multiple regression models to investigate whether individual difference factors (i.e., restraint, as measured by the TFEQ and food addiction symptom count as measured by the YFAS) moderated the association of experimental condition with each of the eating-related dependent variables (i.e., food RRV; self-reported post-RRV food wanting, post-RRV hunger, and liking; RRV food consumption, ad libitum food consumption, and total consumption). We also conducted exploratory analyses using univariate ANOVA to test whether gender interacted with condition to predict each of the eating-related dependent variables.

Results

Aim 1

Relative reinforcing value of food and games. Group means for all dependent variables are presented in Table 2. Participants in the cue-rich environment demonstrated higher food RRV, $F(1, 109) = 5.13$, $p = .03$, $\eta^2 = .05$, compared to those in the neutral environment. Participants in each environment did not differ significantly in game RRV, $F(1, 107) = 0.68$, $p = .41$, $\eta^2 = .01$.

Self-reported food and game wanting. Participants in the cue-rich environment reported significantly higher post-RRV food wanting rating, $F(1, 104) = 6.45$, $p = .01$, $\eta^2 = .06$, than those in the neutral environment. Participants in each environment did not differ significantly in their post-RRV ratings for game wanting, $F(1, 105) = 0.14$, $p = .71$, $\eta^2 = .00$.

Self-reported food and game liking. Participants in each environment did not differ significantly in their self-reported liking for the taste the foods consumed, $F(1, 99) = 0.05$, $p = .82$, $\eta^2 = .00$, enjoyment of eating the foods, $F(1, 99) = 0.11$, $p = .74$, $\eta^2 = .00$, or enjoyment of playing the games, $F(1, 109) = 1.16$, $p = .28$, $\eta^2 = .01$.

Aim 2

Main effect of laboratory environment on post-RRV hunger. Participants in the cue-rich environment reported significantly higher post-RRV hunger ratings, *F*(1,

Table 2. Means and Standard Deviations of Variables of Interest

Variable	Cue-rich M (SD)	Neutral M (SD)	F	p	η^2
RRV calories consumed	740.26 (464.06)	533.80 (388.15)	6.70	.03*	.06
RRV weight consumed (g)	454.19 (247.16)	350.92 (214.82)	5.45	.02*	.05
Ad libitum calories consumed	69.35 (104.70)	77.48 (77.84)	0.11	.74	.00
Ad libitum weight consumed (g)	14.63 (21.79)	15.44 (15.72)	0.05	.83	.00
Total calories consumed	832.49 (467.82)	612.52 (402.28)	6.23	.01*	.06
Total weight consumed (g)	477.89 (247.58)	369.49 (219.41)	5.27	.02*	.05
Food RRV	698.33 (722.40)	432.35 (462.26)	5.13	.03*	.05
Game RRV	946.55 (1047.84)	803.92 (697.13)	0.68	.41	.01
Post-RRV food wanting	3.72 (1.40)	3.10 (1.05)	6.45	.01*	.06
Post-RRV game wanting	3.16 (1.24)	3.24 (1.23)	0.14	.71	.00
Post-RRV hunger	52.47 (20.75)	41.84 (18.90)	7.51	.01**	.07
Food liking of taste	3.43 (0.97)	3.39 (1.18)	0.05	.82	.00
Food enjoyment	2.98 (1.04)	2.91 (1.09)	0.11	.75	.00
Game enjoyment	3.86 (1.24)	3.62 (1.19)	1.16	.28	.01

Note: RRV = relative reinforcing value.
*$p < .05$. **$p < .01$.

110) = 7.51, p = .01, η^2 = .07, than those in the neutral environment.

Baseline hunger interactions. Baseline hunger did not significantly interact with laboratory environment to predict food wanting, liking, or RRV, ad libitum, or total consumption (all ps > .05). There was a trend-level interaction between baseline hunger and laboratory environment to predict food RRV, F(3, 107) = 3.34, β = .25, R^2 = .11, p = .07. For participants in the cue-rich environment, there was a significant, positive correlation between baseline hunger and food RRV, r(60) = .30, p = .02, whereas for participants in the neutral environment there was no significant correlation, r(51) = .02, p = .89. All other interaction p values were .27 or greater.

Aim 3

Food consumption. Participants in the cue-rich environment compared to the neutral environment consumed significantly more calories during the RRV consumption period, F(1, 109) = 6.70, p = .01, η^2 = .06. Participants in each environment did not differ significantly in the number of calories consumed during the ad libitum consumption period, F(1, 97) = 0.11, p = .74, η^2 = .00. This difference remained nonsignificant after controlling for RRV consumption, F(1, 96) = 0.02, p = .88. Participants in the cue-rich compared to neutral environment consumed a greater number of total calories, F(1, 97) = 6.23, p = .01, η^2 = .06.

Mediation models. Post-RRV food wanting (B = 91.25, SE = 48.31, 95% CI [4.23, 196.73], ab_{cs} = .10) and post-RRV hunger (B = 107.89, SE = 49.77, 95% CI [20.39, 219.38], ab_{cs} = .12) were significant mediators in the relationship between environment and total food consumption.

Interactions with individual difference variables

We used separate multiple regression models to examine whether condition interacted with eating-related individual differences measures (i.e., TFEQ restraint, YFAS symptom count) to predict study outcomes. YFAS symptom count significantly interacted with condition to predict ad libitum calories consumed, F(3, 87) = 3.06, β = .34, R^2 = .10, p = .02. For participants in the cue-rich environment, there was a significant, positive correlation between YFAS symptom count and ad libitum calories consumed, r(47) = .37, p = .01, whereas for participants in the neutral environment, there was no significant correlation, r(40) = −.09, p = .56. No other significant interactions were found (all ps >.05).

We used univariate ANOVA to test whether condition interacted with gender to predict study outcomes. No significant interactions were found (all ps >.05).

Discussion

The current study tested IS theory by examining food wanting and liking in both a cue-rich simulated fast-food laboratory and a neutral laboratory environment. Our first aim tested whether wanting and liking were separable in a cue-rich context, as posited by the IS theory (T. E. Robinson & Berridge, 1993). Our second aim investigated whether self-reported hunger differed in a cue-rich compared to neutral context, as hunger has been shown to be affected by environmental cues (Cohen, 2008; A. W. Johnson, 2013). Our third aim tested whether food consumption differed in a cue-rich compared to neutral context, and investigated mechanisms by testing self-reported food wanting and hunger as mediators in the relationship between laboratory environment (i.e., cue-rich or neutral) and food consumption.

Under IS theory, food-related cues play a central role in triggering food wanting, but a less important role influencing food liking. The current study supported this theory. Both food RRV and self-reported food wanting were greater in the cue-rich compared to neutral environment, suggesting that food cues are an important influence on food wanting. However, neither liking for the taste of foods nor enjoyment of eating the foods differed between the two conditions, suggesting that cues are not as important an influence on food liking. Previous studies have had mixed results in illustrating the separability of wanting and liking (Finlayson & Dalton, 2012; Havermans, 2011, 2012). Given that this dissociation is a central tenet of IS theory (T. E. Robinson & Berridge, 1993), the current study's demonstration that wanting and liking are separable in a cue-rich context provides important evidence in support of IS in human eating behavior.

Feelings of hunger are shown to be elevated in the presence of food-related cues (Cohen, 2008; A. W. Johnson, 2013), suggesting that the experience of hunger can be influenced by the environment as well as by homeostatic need. After being exposed to their respective laboratory environments, participants in the cue-rich environment reported experiencing greater hunger than those in the neutral environment. The finding that hunger was greater in the presence of cues suggests that the feelings of hunger were not fully driven by homeostatic need. As this experience was still reported by participants as hunger, it is possible that individuals have difficulty distinguishing homeostatic and cue-driven hunger. This difficulty could contribute to excess consumption in cue-rich environments, as people may begin to feel hungry even when satiated. Thus, feelings of hunger could be a mechanism by which a cue-rich environment contributes to increased food consumption. Although baseline hunger did not significantly interact with condition to predict the dependent variables, there was a trend-level interaction between baseline hunger and environment to predict food RRV. In the cue-rich environment, those who were hungrier at baseline found food even more reinforcing. This suggests that hunger may have marginally amplified participants' response to cues; however, this effect was present only with regard to food RRV. Although research suggests that homeostatic hunger has the ability to moderate one's wanting and liking in response to cues (Berridge et al., 2010), it is possible that non-homeostatic hunger does not interact with cues in the same way. As our self-report measure of hunger did not distinguish between caloric need and non-homeostatic feelings of hunger, future research should do so to further examine how each may differ in response to cues.

Consistent with prior research that people are more prone to eat when cued (Boswell & Kober, 2016; Ferriday & Brunstrom, 2011), participants in the cue-rich compared to neutral environment consumed more calories both in total and during the RRV consumption period. Specifically, participants in the cue-rich environment consumed an average of 219.97 additional calories compared to those in the neutral environment. Consumption of only 148 additional calories per day can lead to a gain of 15 pounds per year (Wellman & Friedberg, 2002). Thus, exposure to the ubiquitous food cues in the American food environment could, over time, lead to weight gain through accumulation of small daily increases in consumption. Furthermore, college students such as those in our sample are also in a developmental stage during which they are making increasingly independent choices about food intake and their food preferences are still being set (Cluskey & Grobe, 2009; Nelson, Kocos, Lytle, & Perry, 2009; Pliner, 1982). As they get older and their metabolism slows (Rowe & Kahn, 1987), the same intake may contribute to more weight gain and obesity. Based on the current results, this possibility may be amplified by exposure to food-related cues. Therefore, although the current sample consisted of individuals currently displaying healthy BMI and few pathological eating symptoms, continued exposure to food cues could put them at risk for weight gain and obesity later in life.

Although the current study observed the ability of food cues to influence excess consumption, this effect did not apply to all foods. Participants in the cue-rich and neutral environments did not significantly differ in their consumption during the ad libitum portion of the protocol. This suggests that there may be some specificity to the impact of food cues on consumption. The foods available during the ad libitum period (e.g., M&Ms, Cheez-Its) are not foods typically consumed in a fast-food restaurant, thus the fast-food cues may not have impacted consumption of these foods as strongly. We used these non-fast-food-related snack foods to minimize any effect of sensory-specific satiety for the fast-food items served earlier in the study. However, it is possible that by using foods incongruent with the context we reduced our ability to induce greater consumption in response to cues. It may be that to trigger increased wanting and consumption, cues must be consistent with the available foods. If this is the case, this knowledge could be used to develop interventions employing the use of congruent or incongruent cues. For example, limiting cues to those for healthy foods (e.g., pictures of fruits and vegetables) in areas such as college dining halls could influence people to consume more healthy and fewer unhealthy foods in that setting. Further research is needed to better understand the effect of cues on wanting for and consumption of foods congruent with the environmental context versus foods incongruent with the environmental context.

The association between cue-rich environment and greater total caloric consumption was mediated by both self-reported food wanting and feelings of hunger. Because food liking did not differ by condition, it does not appear to be a mechanism through which a cue-rich environment is related to greater consumption. Findings from these mediation analyses support IS theory, suggesting that wanting more than liking contributes to elevated consumption in the context of cues. These findings also support a role for feelings of hunger in addition to wanting in increasing food consumption. The current Western food environment is rich with cues for calorie-dense, nutrient-poor foods (e.g., advertisements, vending machines). Given these findings, food wanting and feelings of hunger may be effective targets for interventions aimed at helping people to successfully navigate their exposure to food cues.

Although a strength of the current study is its use of a simulated fast-food laboratory to provide a cue-rich context for the study of eating behavior, such an environment may not be widely available for research testing IS in eating behaviors. Future studies testing IS without the use of such a lab would do well to include cues in multiple sensory modalities (e.g., sight and smell of food, music or other auditory aspects of the restaurant experience, tablecloths or dinnerware simulating those found in a restaurant, etc.) to provide a context with increased ability to trigger wanting and motivation. There is also some evidence that food advertisements may serve as a particularly rich cue, increasing intake (Folkvord, Anschutz, Boyland, Kelly, & Buijzen, 2016; Folkvord, Anschutz, Wiers, & Buijzen, 2015). Future studies could employ food advertisements or commercials as aspects of the cued environment when testing IS in eating behavior.

Although individuals with higher levels of eating pathology (e.g., restraint, food addiction) may be more responsive to cues (Fedoroff et al., 2003; Franken, 2003), we did not find interactions between eating pathology and cue-exposure on wanting, hunger, or consumption in the current study, with one exception. Participants higher in food addiction symptoms consumed significantly more calories during the ad libitum period in the cue-rich environment compared to the neutral environment. Although it seems that for healthy individuals, cues must be congruent with the available foods to trigger excessive consumption, it is possible that for those with more addictive-like eating, cues can trigger increased consumption of any highly processed food, even if they are not consistent with the cue. With regard to restraint, there is evidence that restrained eaters consume more of a food after receiving a priming taste of that food (Cornell et al., 1989). Thus, it may be that for those high in restraint, it is necessary to consume a small portion of a "forbidden" food to trigger a feeling of rule violation, in turn increasing further consumption. However, the current sample endorsed a restricted range of food addiction symptoms, so our ability to generalize to more clinical samples is limited. Future research on populations with specific eating pathologies (e.g., restraint, food addiction) will provide further insight into how those symptoms interact with cues to affect consumption.

The current study also did not find any significant interaction between gender and condition to predict eating-related study outcomes. Although gender differences in eating behavior have been shown (Rolls, Federoff, & Guthrie, 1991), there is mixed evidence for gender differences in reactivity to cues for various substances (e.g., food, cigarettes, alcohol, cocaine). Several studies show no difference in overall cue reactivity (Robbins, Ehrman, Childress, & O'Brien, 1999; Rubonis et al., 1994; Sobik, Hutchison, & Craighead, 2005), but some differences have been noted. For example, women are more likely to respond to a cue after induction of negative affect (Rubonis et al., 1994) and are more likely to show elevated craving as a cue-induced response (Robbins et al., 1999; Sobik et al., 2005). Although we did not see gender differences in the current study, it is possible that manipulating conditions such as stress or negative affect would result in the detection of gender differences in the response to food cues.

The current study has some limitations that should be addressed through future research. Our sample exhibited a restricted BMI range, thus we did not find any significant relationships between BMI and our variables of interest. A sample with a wider BMI range will be better able to demonstrate how cues influence eating behavior in individuals who are obese. Prior research has found an association between obesity and cue reactivity (Sobik et al., 2005; Tetley, Brunstrom, & Griffiths, 2009), thus perhaps the effects of our cue-rich context would be even more pronounced in individuals with obesity. Similarly, our sample was also relatively healthy, limiting generalizability to more clinical samples. As IS theory was developed in relation to addictive disorders, we may expect cue-triggered wanting, hunger, and consumption to be amplified in individuals meeting criteria for food addiction. Future studies with a greater proportion of individuals with clinically significant food addiction would have greater power to thoroughly examine this effect.

Due to the structure of the RRV paradigm, food RRV was inherently linked with total consumption, preventing us from testing food RRV as a mediator in the relationship between laboratory environment and consumption. To test food RRV as a mechanism, future studies may be designed such that this variable is not linked to the outcome of interest, for example, by providing unlimited access to the RRV foods rather than restricting access based on points earned. In addition, as self-reported wanting and hunger ratings in the laboratory environment were obtained after the RRV task, it is possible that these ratings were influenced by task performance (e.g., individuals reported being hungrier because they had just worked hard for food) due to cognitive dissonance in which attitudes are shifted to reflect prior behaviors (Brehm, Back, & Bogdonoff, 1964). We believe that our findings of increased self-reported wanting and hunger in the cue-rich environment, in combination with our finding of increased food RRV in the cue-rich environment, provides strong evidence for the ability of cues to trigger increased food motivation. However, future studies would do well to measure self-reported wanting and hunger in the presence of cues before any behavioral task to ensure that any increase seen is due to cues. Finally, food liking measurements were taken at the end of the study and outside of the laboratory environment. It is possible that liking ratings would have been higher if obtained in the laboratory environment, and that measuring liking outside the environment may have reduced the effect of cues. Future studies should assess liking while in cue-rich versus neutral environments to ensure all effects are fully captured.

The current study builds on prior research on the role of cues in consummatory behaviors, examining food wanting and liking in a simulated fast-food laboratory. Unlike prior studies, which used food images or smells alone as cues, we observed a strong distinction between food wanting and liking in our cue-rich environmental context. These results have important implications for efforts to reduce overeating and obesity. Unhealthy food cues are ubiquitous in the Western food environment, possibly leading to greater wanting and experiences of hunger, which may be difficult to resist and result in overeating even for healthy individuals. In those with obesity or eating-related pathology, cue reactivity could be even more pronounced, although future research is needed. The current study's findings on the impact of cues suggest that modifying one's exposure and response to these cues could be an effective target for interventions targeting overeating. As food-related cues appear to be powerful influences on overeating even in healthy individuals, it may be helpful for people to identify triggering settings where they may be exposed to unhealthy food cues (e.g., fast-food restaurant) and take steps to either limit their exposure to these settings or mitigate their response. For example, people may choose to take their meal to go, rather than dining in a fast-food restaurant, so they are less affected by the presence of cues during their meal.

Given the mediating role of wanting and hunger, treatments aimed at responding to feelings of wanting and hunger may also be effective. For example, mindfulness techniques such as "urge surfing," or learning to ride out a craving without giving in to it, have shown effectiveness in treatment of substance use disorders (Bowen & Marlatt, 2009). Recognizing these feelings and learning strategies to respond to them more effectively help people feel better equipped to resist the strong, cue-triggered urge to consume unhealthy food. Finally, strong evidence that excessive consumption of unhealthy foods is impacted by environmental cues has the potential to influence policy approaches that could reduce the ubiquity of some types of cues (such as restrictions on food advertising). Although additional research is needed to determine the effect of cues across populations and situations, the current study demonstrates that IS principles appear to be at play in eating behaviors and justifies further study.

Author Contributions

M. A. Joyner and A. N. Gearhardt developed the study concept and design. Data collection was performed by M. A. Joyner and S. Kim. M. A. Joyner and A. N. Gearhardt performed the data analysis and interpretation. M. A. Joyner drafted the manuscript with contributions from S. Kim, and A. N. Gearhardt provided critical revisions. All authors approved the final version of the manuscript for submission.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Note

1. Five participants were missing data from the post-RRV survey measures (i.e., food and game wanting, hunger) due to errors saving the data. Ten participants did not complete all items from the YFAS, and thus do not have a food addiction symptom

count score. The ad libitum protocol described in this article was added to the study after 12 participants had already taken part, thus ad libitum and total consumption data are included only for those who took part after the ad libitum protocol was added to the study.

Supplemental Material

Additional supporting information may be found at http://journals.sagepub.com/doi/suppl/10.1177/2167702617718828.

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