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The Smell of Healthy Choices: Cross-Modal Sensory Compensation Effects of Ambient Scent on Food Purchases

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Abstract

Managers are using ambient scent as an important strategic element in various service settings, with food-related scents being especially common. This research examines the effects of food-related ambient scents on children's and adults' food purchases/ choices. The results of a series of experiments, including field studies at a supermarket and at a middle school cafeteria, show that extended exposure (of more than two minutes) to an indulgent food–related ambient scent (e.g., cookie scent) leads to lower purchases of unhealthy foods compared with no ambient scent or a nonindulgent food–related ambient scent (e.g., strawberry scent). The effects seem to be driven by cross-modal sensory compensation, whereby prolonged exposure to an indulgent/ rewarding food scent induces pleasure in the reward circuitry, which in turn diminishes the desire for actual consumption of indulgent foods. Notably, the effects reverse with brief (<30 seconds) exposure to the scent. Whereas prior research has examined cross-modal effects, this research adopts the novel approach of examining cross-modal sensory *compensation* effects, whereby stimuli in one sensory modality (olfactory) can compensate/satisfy the desire related to another sensory modality (gustatory).

Keywords

ambient scent, cross-modal sensory compensation effects, (un)healthy food choices, retail and service setting atmospherics, sensory marketing

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Marketers are increasingly using ambient scent as a strategic tool to differentiate from the competition, attract customers, stimulate sales, influence mood, and create an overall pleasant and memorable shopping experience (Madzharov, Block, and Morrin 2015). For instance, ambient scents are often infused in retail stores, supermarkets, hotels, restaurants/cafeterias, airplanes, and arenas/stadiums. While managers have traditionally focused on ambient sensory factors related to visual and auditory cues, there is a growing trend toward focusing on olfactory cues as a strategic element in retail atmospherics (Nassauer 2014). For example, Samsung pumps the scent of honeydew melons into its flagship store in New York (Strutner 2015). Table 1 outlines additional examples of ambient scent usage in the marketplace.

Although managers use different types of ambient scents, food-related ambient scents are especially common (see Table 1). In a recent trend, restaurants are adding artificial ambient scents of foods that may not even be on their menus. For instance, Chicago-based Alinea restaurant uses burning cinnamon sticks and branches of fresh rosemary as an ambient scent; Cleveland-based Vita Urbana uses the smell of burned bay leaves and heated cilantro as an ambient scent, even though the chef does not put cilantro into the dishes (Glazer 2017).

Given the prominence of ambient scent as a marketing tool and the popularity of food-related ambient scents in the marketplace, this research examines the influence of food-related ambient scents on consumers' product choices. We focus specifically on how ambient scents related to indulgent (i.e., unhealthy) and nonindulgent (i.e., healthy) foods influence children's and adults' choices of unhealthy (vs. healthy) food options. We focus on the choice of healthy/unhealthy foods as the outcome variable, due to growing worldwide concerns about unhealthy eating and rising obesity rates (Biswas et al. 2017; Chandon and Wansink 2007).

Examining the effects of indulgent versus nonindulgent food–related ambient scents on food choices has strong practical and conceptual implications, because managers of retail

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Table 1. Marketplace Examples of Food-Related Ambient Scents.

Company	Example
Alinea Restaurant (Chicago)	Uses burning cinnamon sticks and branches of fresh rosemary as an ambient scent (Glazer 2017)
Disney theme parks	Places scent-emitting machines strategically throughout their parks to disperse scents of cotton candy, popcorn, and caramel apples (Hari 2015)
Hamleys (London-based toy retailer)	Uses piña colada as the ambient scent in its stores (White 2011)
Hard Rock Hotel (at Universal Orlando Resort)	Has scent of sugar cookies at the top of a staircase and scent of waffle cones at the bottom with goal of drawing customers to its lower-level ice cream shop (Hari 2015; Kobliner 2017)
Hugo Boss stores	Ambient scent contains light accents of fruits and citrus with a hint of cocoa, among other scents (Klara 2012)
Kimpton Hotel Monaco	Uses a blend of citrus and green tea floats diffused from "air machines" (Klara 2012)
Net Cost (supermarket chain)	Uses ambient scents of chocolates and baked breads (Hari 2015)
Samsung	Pumps the scent of honeydew melons in its flagship store in New York (Klara 2012)
Singapore Airlines	Uses a signature scent, called "Stefan Floridian Waters" (a combination of citrus, lavender, and rose scents, among others) in the cabins of its airplanes. This scent is also infused in their towels (Klara 2012; Strutner 2015).
Sonesta Hotels	Uses green tea–based ambient scent (Kaufman 2017)
Stadiums and indoor arenas	Barclays Center (indoor arena in Brooklyn) diffuses an ambient scent with citrus notes. Other examples include AT&T Stadium in Arlington, Texas, State Farm Arena in Atlanta, and The Dome at America's Center in St. Louis (Doll 2013; Martinez 2013).
United Airlines	Their signature fragrance is a combination of orange and fir tree scents; this scent is being pumped into some jet bridges and member lounges and is infused in the hot towels in some premium cabins (Strutner 2015).
Vita Urbana Restaurant (Cleveland)	Uses the smell of burned bay leaves and heated cilantro in the ambience even though the chef does not put cilantro into the dishes (Glazer 2017)

stores, supermarkets, and restaurants can easily change the ambient scent by strategically using scent nebulizers. From a health perspective, dietary regulations are generally restrictive in nature and can induce reactance (Yee 2012). In contrast, ambient scent influences behavior in a nonrestrictive manner and is less likely to induce resistance or reactance (as restrictive policies might); thus, it can be more effective. Conceptually, the findings of our research enhance our understanding of cross-modal sensory effects, in terms of an olfactory cue (i.e., ambient scent) influencing a gustatory-related (i.e., food choice) outcome. In addition, whereas prior research has examined how different factors influence choices for healthy options (e.g., Biswas et al. 2017; Dhar and Wertenbroch 2012; Shiv and Fedorikhin 1999), the present research, to the best of our knowledge, is the first to examine the effects of ambient scents on choices between healthy and unhealthy options.

Next, we develop a set of hypotheses that predict how food-related ambient scents can influence food choices. We propose a cross-modal sensory compensation model, whereby exposure (of more than two minutes) to an indulgent food scent induces pleasure in the reward circuitry of the brain, which in turn diminishes the desire for actual consumption of indulgent foods.

Theoretical Background

Cross-Modal Sensory Effects

Human beings have multiple sensory systems (visual, olfactory, auditory, gustatory, and haptic) to experience the environment, with each of these sensory systems providing subjective interpretations of the surrounding world (Calvert 2001). In addition, inputs from different sensory systems often influence each other (Small, Veldhuizen, and Green 2013). Research in neuroscience has identified several multisensory brain regions as convergence zones where inputs from different sensory modalities combine, interact, and influence each other (Driver and Noesselt 2008; Van Atteveldt et al. 2014). In that regard, the olfactory and gustatory systems are especially interconnected (De Araujo et al. 2003; Gagnon et al. 2014; Rolls 2008).

The olfactory, gustatory, and trigeminal (which responds to irritants in the mouth) systems make up the chemosensory system, which is responsible for flavor perception (Lundstrom, Boesvelt, and Albrecht 2011). The olfactory and gustatory systems largely overlap in the orbitofrontal cortex of the brain (De Araujo et al. 2003; Gagnon et al. 2014). The interconnection of the gustatory and olfactory systems has important implications for cross-modal sensory effects, which relate to stimuli presented in one sensory modality influencing perceptions, behavioral responses, or processing of stimuli presented in another sensory modality (Senkowski, Hofle, and Engel 2014). Table 2, Panel A, summarizes the key findings in this domain.

Research in the domain of cross-modal sensory effects has demonstrated several notable findings (for details, see Table 2, Panel A). The focus of the present research is on cross-modal sensory *compensation* effects of olfactory cues (i.e., ambient scent) satisfying desire related to gustatory outcomes (i.e., food choices). Before discussing how olfactory inputs related to ambient scent influence food choices, we discuss the reward system related to food.

Table 2. Summary of Relevant Literature.

A: Literature on Cross-Modal Sensory Effects and Sensory Interaction Effects

	IV(s)	DV(s)	Relevant Conclusions/Findings
Research			
Calvert (2001)	Review paper		Sensory systems are integrated in the brain.
De Araujo et al. (2003)	Exposure to olfactory cues only (vs. gustatory cues only vs. olfactory and gustatory cues vs. control)	Brain activation captured through fMRI	Activation in the anterior orbitofrontal cortex was greater when olfactory and gustatory stimuli were presented in combination.
Driver and Noesselt (2008)	Review paper		Sensory systems converge in the brain.
Gagnon et al. (2014)	Olfactory impairment (vs. normal olfactory capability)	Taste identification	Olfactory and gustatory systems jointly contribute to flavor evaluations with the effects moderated by olfactory ability. Individuals with impaired (vs. normal) olfactory ability were less accurate in identifying tastes.
		Brain activation captured through fMRI	Activation in the medial orbitofrontal cortex was greater among individuals with normal olfactory capability.
Krishna, Elder, and Caldera (2010)	Congruence (vs. incongruence) between olfactory and haptic cues	Product evaluation	Products feel better when the scent and texture or temperature are congruent in terms of both being masculine or feminine. These effects are moderated by the gender and temperature associations of the scent.
		Haptic perception	Congruency between the sensory cues is the underlying mechanism. That is, congruence between haptic and olfactory cues increases haptic perception and product evaluations.
Lundstrom, Boesveldt, and Albrecht (2011)	Review paper		Studies in neuroimaging have consistently demonstrated that the areas of the brain associated with taste (e.g., super frontal, anterior insular, cingulate gyri, middle frontal) strongly respond to olfactory stimuli.
Maier, Wachowiak, and Katz 2012	Exposure to multiple gustatory and olfactory stimuli	Activation in the primary olfactory cortex	The primary olfactory cortex is activated by gustatory stimuli.
Mediavilla, Martin-Signes, and Risco (2016)	Induced conditioned flavor preference (vs. control)	Activation in the piriform cortex	Activation in the piriform cortex (a region of the brain with an important function related to the sense of smell) was greater after conditioned flavor preference.
Rolls (2008)	Review paper		The olfactory and gustatory systems are interconnected.
Small, Veldhuizen, and Green (2013)	Review paper		Olfactory and gustatory sensory systems converge in the posterior piriform olfactory cortex.
Van Atteveldt et al. (2014)	Review paper		Sensory systems are integrated in the brain.
Vroomen and De Gelder (2000)	Presence (vs. absence) of an auditory cue with the visual target	Detection of a visual target	Detection of a visual target is enhanced when it is presented synchronously with an auditory cue. Specifically, individuals identify visual targets more quickly when the target is presented simultaneously with a high-pitched sound.
Zellner and Kautz (1990)	Color of solution (red vs. colorless)	Perceived smell	Strawberry-scented solutions were rated as smelling stronger when colored red than when colorless.

B: Literature on Satiation

Category	Research	Relevant Conclusions/Findings
General satiation and sensory specific satiety	Inman (2001)	Sensory-specific satiety leads to reduced hedonic responses and decreased pleasantness to foods as the foods are consumed. Consumers are more likely to satiate on sensory attributes of products (e.g., food flavor) than on nonsensory attributes (e.g., brand).
	Redden and Haws (2013)	Consumers higher in trait self-control satiate faster on unhealthy foods than on healthy foods, with no such consistent effects for consumers with lower self-control.
Scent-induced satiation	Biswas et al. (2014)	Exposure to similar sensory cues leads to satiation. When sampling a series of products (e.g., foods, beverages, fragrances) with similar sensory aspects (e.g., scents), satiation leads to primacy effects and a

(continued)

Table 2. (continued)

B: Literature on Satiation

Category	Research	Relevant Conclusions/Findings
		greater preference for the first sampled product. The findings imply that prolonged exposure to a certain scent can induce satiation and subsequently reduce liking of products related to that scent.
	Nowlis, Shiv, and Wadhwa (2008)	Exposure to a food-related ambient scent (i.e., popcorn) or a nonfood-related ambient scent (i.e., lavender) versus no scent led to decreased consumption of the food cued (popcorn). However, the authors did not examine cross-modal effects of ambient scent on food choices.
	Rolls and Rolls (1997)	Smelling a food for approximately the same amount of time as it would take to chew/consume the food leads to reduced pleasantness of the food.

C: Literature on Effects of Emotion on Food Consumption

Category	Research	Relevant Conclusions/Findings
Positive emotions	Evers et al. (2013)	Positive emotion led to more caloric intake.
	Winterich and Haws (2011)	Hopefulness leads to lower level of unhealthy food consumption.
Negative emotions	Baumeister (2002)	When people experience sadness, they tend to eat unhealthy foods.
	Salerno, Laran, and Janiszewski (2014)	Sadness heightens consumers' sensitivity to the possible harmful consequences of indulgent consumption, which in turn decreases indulgence when a hedonic goal is salient.

D: Nonmarketing Literature on Children's Food Choices

Research	Relevant Conclusions/Findings
Cullen and Zakeri (2004)	Middle school students consumed fewer healthy foods when there was greater access to snack bars at schools.
Lytle et al. (2000)	There is a significant difference in consumption of healthy foods by third- versus eighth-graders, with the latter consuming significantly smaller amounts of healthy foods.
Wordell et al. (2012)	Two (out of six middle schools) stocked only bottled water in vending machines, had milk and fruit on à la carte menus, and had a fruit and vegetable bar. The findings of the study were mixed. While consumption of pastries and juice declined in the intervention schools, there were no differences in fruit and vegetable consumption between the control and intervention schools.
Young, Fors, and Hayes (2004)	Parental guidance can be effective in influencing consumption of fruits and vegetables by middle school children.

Notes: IV = independent variable; DV = dependent variable; fMRI = functional magnetic resonance imaging.

Rewarding Aspects of Food-Related Sensory Cues

When exposed to a food-related sensory cue, such as a food-related ambient scent, the sensations associated with the cue/stimulus are first sent, for identification, to the area of the brain that processes that type of sensory cue (Schultz 2002). Interestingly, olfactory and gustatory cues are processed in the same region of the brain (see Table 2, Panel A). Once identified, sensory cues are then fed to the orbitofrontal cortex, where their reward value (i.e., subjective pleasantness) is assessed (Camerer, Loewenstein, and Prelec 2005).

The orbitofrontal cortex discriminates between stimuli on the basis of the valence (i.e., positive, negative, or neutral) as well as the intensity of the reward value (e.g., positive vs. extremely positive) (Hollerman, Tremblay, and Schultz 1998; Tremblay and Schultz 1999). The reward value assigned to a stimulus is a function of a combination of factors, such as hunger level and prior experience with the stimulus (Camerer, Loewenstein, and Prelec 2005). However, certain types of food-related stimuli are particularly rewarding: high-calorie, high-fat, and sugar-laden (i.e., indulgent) foods tend to have the highest reward values (Rolls 2011).

Once a stimulus with a high reward value is identified, the brain's reward circuitry, primarily composed of the dopamine system, is activated (Camerer, Loewenstein, and Prelec 2005; Wise 2002). Although reward systems discriminate among stimuli that vary in intensity of reward value, they do not discriminate among the sensory modalities in which the stimuli are encoded (Schultz 2002). Thus, foods do not have to be eaten to activate reward circuitry; rather, nongustatory food-related sensory cues can also activate reward centers (Schultz 2002). For instance, Frank et al. (2010) found that showing people pictures of high- (vs. low-) calorie foods increased activity in the brain's reward centers. Along similar lines, studies show that sniffing pizza and chocolate chip cookies increases reward activation (Krishna, Morrin, and Sayin 2014). At a broader level, pleasurable, pleasant, or rewarding stimuli in the external environment activate the reward circuitry in the brain (Camerer, Loewenstein, and Prelec 2005; Schultz 2002); moreover, rewarding sensory stimuli in the environment lead to overall pleasant feelings (Ressler 2004).

Building on these research streams, we propose that olfactory cues related to indulgent foods will have similar effects on the brain's reward circuitry. Specifically, an ambient scent related to an indulgent (vs. nonindulgent) food will activate the reward circuitry in the brain. Next, we discuss how reward circuitry activation influences subsequent food choices.

Cross-Modal Sensory Compensation and Food Choices

At a fundamental level, when choosing between healthy and unhealthy foods, the trade-off is usually between opting for foods that are consistent with long-term health goals or succumbing to short-term temptations for tastier, higher-calorie options (Biswas et al. 2017; Raghunathan, Naylor, and Hoyer 2006; Romero and Biswas 2016; Winterich and Haws 2011). Foods that are perceived as tastier tend to be high in sugar, calories, fat, and salt. These are the types of foods that satisfy the "reward center" of the brain (Menzies 2012; Small et al. 2001; Volkow, Wang, and Baler 2011). For instance, Small, Jones-Gotman, and Dagher (2003) found that eating one's favorite meal leads to dopamine release, which is associated with pleasure and reward activities in the brain. One of the reasons for obesity is related to the physiological need to satisfy the reward circuits in the brain with palatable foods that are high in sugar, fat, and calories (Stice et al. 2013). In essence, pleasure and reward associated with the brain play critical roles in influencing choices for tasty, unhealthy foods. In other words, a key reason people consume unhealthy (i.e., indulgent) foods is because doing so is rewarding and pleasurable (Kringelbach et al. 2003).

Notably, the experienced pleasure is associated with the predictors of reward rather than the receipt of reward, because the dopamine systems are aroused more by the sensory cues that predict receipt of the reward (e.g., the sight or smell of food) than they are by the actual receipt of the reward (Wise 2002). Along with palatable foods, the reward circuitry in the brain is also activated by sex, drugs, smoking, and alcohol, among other stimuli (Wise 1996, 2002). Moreover, stimuli that satisfy the reward circuitry can be interchanged and substituted. For example, studies show that when people give up smoking, they substitute increased intake of food calories for cigarettes to satisfy the brain's reward circuits (Spring et al. 1991).

As stated previously, the olfactory and gustatory systems are strongly interconnected (see Table 2, Panel A), and reward centers in the brain do not distinguish between stimuli encoded by different sensory systems (Schultz 2002). Building on these ideas, we propose that if the reward circuitry in the brain can be satisfied with nongustatory sensory inputs, it can reduce the need to seek those rewards from actual gustatory food consumption. That is, we propose that cross-modal sensory compensation effects are the mechanism by which sufficient exposure to an ambient scent of an indulgent food item causes the reward circuitry of the brain to be satisfied by the olfactory inputs of something tasty and unhealthy. This, in turn, reduces the desire to consume indulgent (i.e., unhealthy) foods.

In contrast, the presence of a nonindulgent food–related ambient scent or no ambient scent will not have any such effects, because of their lower reward value. In other words, we are proposing a cross-modal sensory compensation effect, whereby experiencing an indulgent food–related ambient scent for an extended duration diminishes the desire for actual consumption of indulgent foods.

Research in the domain of satiation provides additional support for our claims linking prolonged exposure to indulgent (vs. nonindulgent) ambient scents to reduced choices for unhealthy foods (for details, see Table 2, Panel B). Specifically, research has shown that prolonged exposure to a certain scent can induce satiation and subsequently reduce the desire or liking for products related to that scent (Biswas et al. 2014; Nowlis, Shiv, and Wadhwa 2008; Rolls and Rolls 1997).

In summary, the arguments pertaining to cross-modal sensory compensation and the related effects of sensory satiation would predict that sufficient exposure to an indulgent (vs. nonindulgent) food–related ambient scent will decrease preference for unhealthy options and correspondingly enhance preference for healthy options. Formally stated,

H_1: Extended exposure to an indulgent (vs. a nonindulgent) food–related ambient scent leads to lower choice likelihood of unhealthy items.

H_2: The effects predicted by H_1 are mediated by the perceived rewarding experience induced by the ambient scent. Specifically, extended exposure to an indulgent (vs. a nonindulgent) food–related ambient scent enhances the perceived reward associated with the experience, which in turn leads to lower choice likelihood of unhealthy items.

Alternative Account

Notwithstanding H_1, a possible alternative account related to priming effects would predict different outcomes. Research in the domain of priming effects (Aggarwal and McGill 2012; Forehand and Deshpandé 2001) would suggest that the presence of an indulgent (nonindulgent) food–related olfactory cue will prime greater preference for unhealthy (healthy) foods. For instance, exposure to scented (vs. unscented) advertisements can increase consumption of the advertised food (Krishna, Morrin, and Sayin 2014); thus, priming effects would predict an opposite pattern of effects from H_1. We elaborate on this in a subsequent section and demonstrate in Study 4 the moderating conditions that favor outcomes consistent with the sensory compensation model versus the priming model.

We tested our hypotheses with the help of field and lab studies. Table 3 provides an overview of the field and lab experiments.

Table 3. Summary of Results by Study Condition.

A: Proportion of Total Sales in Study 1a (8,629 Items Sold; Field Experiment)

	Indulgent Food Ambient Scent (Pizza; 2,931 Items Sold)	Nonindulgent Food Ambient Scent (Apple; 2,819 Items Sold)	No Scent (2,879 Items Sold)
Unhealthy items	21.43%	36.96%	36.54%
Unhealthy beverages	5.86%	7.78%	7.30%
Unhealthy foods	27.64%	46.37%	46.15%
Main finding	There were lower sales of unhealthy items when the ambient scent was related to an indulgent food (vs. a nonindulgent food or no scent).		

B: Choice Share of Unhealthy Item and Preference for Healthy Item in Study 1b (N = 216; 51% Female, M_{age} = 22 Years; Lab Experiment)

	Indulgent Food Ambient Scent (Cookie; N = 120)	Nonindulgent Food Ambient Scent (Strawberry; N = 96)
Choice share: cookie	35.0%	50.0%
Preference for healthy item (strawberry; 1–7 scale)	4.68 (2.35)	3.94 (2.40)
Main finding	An indulgent food related ambient scent led to reduced preference for the unhealthy item.	

C: Proportion of Unhealthy, Healthy, and Neutral Items Purchased, Per Customer, in Study 2 (N = 128; Field Experiment)

	Indulgent Food Ambient Scent (Chocolate Chip Cookie; N = 52)	Nonindulgent Food Ambient Scent (Strawberry; N = 76)
Proportion of unhealthy items purchased	29.53%	45.41%
Proportion of healthy items purchased	39.14%	25.68%
Proportion of neutral/nonfood items purchased	31.32%	28.91%
Total number of items	5.62	6.93
Total bill amount	$25.06	$31.03
Main finding	Exposure (for more than two minutes) to an indulgent (vs. nonindulgent) ambient scent leads to lower (higher) degree of unhealthy (healthy) food purchases.	

D: Proportion of Unhealthy Items Purchased and Perceived Reward Associated with the Experience in Study 3a (N = 78; 49% Female; M_{age} = 12.88 Years; Field Experiment)

	Indulgent Food Ambient Scent (Cookie; N = 41)	Nonindulgent Ambient Scent (Apple; N = 37)
Choice share: unhealthy food	46.34%	70.27%
Perceived reward associated with the experience	4.51 (1.26)	3.68 (1.78)
Main finding	Perceived reward associated with the experience mediates the effect of food related ambient scents on food choices.	

E: Preference for Healthy Item and Perceived Reward Associated with the Experience in Study 3b (N = 117; 41% Female; M_{age} = 22 Years; Lab Experiment)

	Indulgent Food Ambient Scent (Cookie; N = 59)	Nonindulgent Food Ambient Scent (Strawberry; N = 58)
Preference for unhealthy item (i.e., chocolate cake)	2.88 (2.13)	3.76 (2.35)
Perceived reward associated with the experience	4.68 (1.09)	4.28 (1.08)
Main finding	Indulgent (vs. nonindulgent) food scent reduces preference for the unhealthy item and this effect is mediated by perceived reward associated with the experience.	

F: Choice Share of Unhealthy Item in Study 4 (N = 257; 54% Female; M_{age} = 22 Years; Lab Experiment)

	Indulgent Scent, High Duration of Exposure (N = 50)	Nonindulgent Scent, High Duration of Exposure (N = 77)	Indulgent Scent, Low Duration of Exposure (N = 58)	Nonindulgent Scent, Low Duration of Exposure (N = 72)
Choice share: unhealthy item (cookie)	22.00%	40.26%	44.83%	27.78%
Main finding	High duration of exposure to an indulgent (vs. nonindulgent) food–related ambient scent decreased choice for unhealthy items. Low duration of exposure to an indulgent (vs. nonindulgent) food–related ambient scent increased choice for unhealthy item.			

(continued)

Table 3. (continued)

G: Preference for Healthy Item in Study 5 (N = 172; 51% Female, M_{age} = 23 Years; Lab Experiment)			
	Indulgent Food Ambient Scent (Cookie; N = 50)	Nonindulgent Food Ambient Scent (Strawberry; N = 70)	No Scent (N = 52)
Preference for the healthy item (salad)	4.30 (2.11)	3.33 (2.36)	3.35 (2.29)
Main finding	The effects of exposure to an indulgent (vs. a nonindulgent) food–related ambient scent on food preference hold for consumers with moderate and high scent-identification proficiency and get weakened for consumers with low scent-identification proficiency.		

H: Additional Field Study (Not Reported in the Article) Conducted at School Cafeteria with À La Carte Menu Orders (N = 72; Field Experiment)		
	Indulgent Food Ambient Scent (Pizza; N = 42)	Nonindulgent Food Ambient Scent (Strawberry; N =30)
Choice share: unhealthy food	83.33%	100%
Main finding	An indulgent food–related ambient scent led to reduced preference for the unhealthy items on the à la carte menu (χ^2 = 5.54, p < .05).	

Notes: Standard deviations are in parentheses.

Study 1a: Field Experiment at Middle School Cafeteria

Method

We tested H_1 in Study 1a, a field experiment conducted in the cafeteria of a middle school in one of the largest school districts in the United States. The experiment was conducted in collaboration with the district school board and the school administration. The study was a between-subjects experiment with three manipulated conditions (ambient scent related to nonindulgent food vs. indulgent food vs. control condition of no scent). These three conditions were randomly run across three different days.

Apple scent and pizza scent were the nonindulgent (healthy) and indulgent (unhealthy) ambient scents, respectively. To manipulate ambient scent, commercial grade scent nebulizers were strategically and unobtrusively placed near the entrance of the cafeteria where students were lined up. The nebulizers used across all our studies were Wyndmere brand ultrasonic nebulizers. Apple and pizza scent oils were purchased from Air Essentials. Seven drops of the scented oil and about seven fluid ounces of distilled water were added to the chamber of the nebulizer. The entry of the students to the cafeteria was deliberately slowed down near the nebulizer so that the students received prolonged exposure (of more than two minutes) to the ambient scent. The scent nebulizer was switched on about 30 minutes before the start of the first lunch period. The intensity levels of the two different scents were kept similar (using the nebulizer regulator).

The middle school where the field experiment was run had a total student enrollment of approximately 900. The school is located in a low-income, working-class neighborhood. More than 80% of the students at this school are eligible for free or reduced-price lunch, indicating a high proportion of economically underprivileged children. We opted for this school's cafeteria because we wanted to examine the effects with economically disadvantaged children, who are at especially high risk of obesity (Drewnowski and Spector 2004). Moreover, the student population at this school is quite diverse, enabling us to collect data across many major racial groups; the student body is approximately 36% Caucasian, 32% Hispanic, 24% Black, 2% Asian, and 6% multi/undisclosed/other races. About 48% of the students are female.

The key dependent measure was the healthiness or unhealthiness level of food purchased at the cafeteria. Data for the food sold at the cafeteria were obtained from the district school board. We focused on the proportion of unhealthy foods and beverages purchased out of the total number of items sold during the lunch periods. Interestingly, children become quite good at categorizing foods as healthy versus unhealthy at a young age (Nguyen 2007). Thus, our coding of food items as healthy/unhealthy is reasonable. The items sold at the school cafeteria were coded a priori as healthy versus unhealthy by a trained researcher who was blind to the experimental conditions. Items were coded as healthy/unhealthy drawing on currently used standards (Biswas et al. 2017). Specifically, fruits, vegetables (e.g., salad), milk, crackers, fruit snacks, bottled water, and grilled/baked white meat (e.g., chicken, turkey) were coded as healthy, whereas chips, fries, hot dogs, fried chicken, Rice Krispies treats, Gatorade, and fruit cobbler were coded as unhealthy.

Results and Discussion

The results support H_1 (see Table 3, Panel A, and Figure 1, Panel A). On the day of the pizza ambient scent, a total of 2,931 food/beverage items were sold, out of which 628 items (21.43%) were unhealthy. On the day of the apple ambient scent, a total of 2,819 items were sold, out of which 1,042 items (36.96%) were unhealthy. On the day of the control condition (no scent), a total of 2,879 items were sold, out of which 1,052

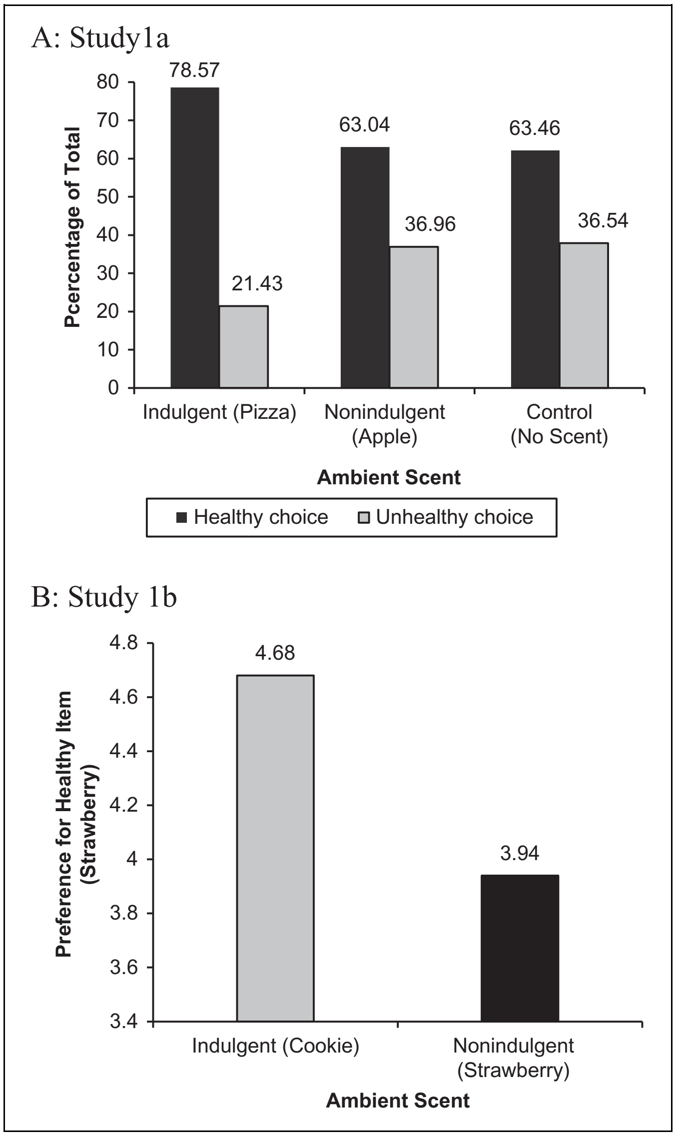


Figure 1. Key results of Study 1.

items (36.54%) were unhealthy. There was an overall main effect of ambient scent on type of item (unhealthy vs. healthy) purchased ($\chi^2 = 226.59$, $p < .001$). Follow-up tests showed that a lower percentage of unhealthy items were purchased at the school cafeteria when the ambient scent was related to pizza versus apple condition (21.43% vs. 36.96%; $\chi^2 = 168.33$, $p < .001$) or versus the control (no-scent) condition (36.54%; $\chi^2 = 161.42$, $p < .001$). There was no difference in purchase of unhealthy items when the ambient scent was apple versus no scent ($\chi^2 = .11$, $p = .74$).

We also conducted the analyses for beverages and foods separately to see where the effects were coming from. For the beverages, milk and water were the healthy options, and Gatorade was the unhealthy option. Ambient scent did not have any significant effects on purchases of unhealthy beverages ($p > .10$ for all comparisons), although the indulgent scent led to directionally lower sales of unhealthy beverages (see Table 1, Panel A).

The indulgent ambient scent led to lower sales of unhealthy foods compared with the nonindulgent ambient scent ($\chi^2 = 158.90$, $p < .001$) or the no-scent ($\chi^2 = 156.48$, $p < .001$) conditions. Nonindulgent (vs. no) ambient scent led to similar outcomes ($\chi^2 = .02$, $p = .89$).

Study 1b: Replication in Controlled Lab Setting

Method

Pretest. We conducted a pretest (n = 61) to ensure that participants would associate the ambient scents (cookie and strawberry) with foods. See Web Appendix A for the pretest details.

Main study. Study 1b had two between-subjects conditions (ambient scent: indulgent vs. nonindulgent). Participants arrived at the waiting area of a lab and were subsequently brought into the lab by a research assistant. Participants were first given a filler task with a set of questions (see Web Appendix A) to ensure that they were exposed to the ambient scent for an extended period (of more than two minutes) of time.

The ambient scent in the lab was manipulated with the help of the same ultrasonic scent nebulizer as used in Study 1a. The nebulizer was strategically and unobtrusively placed in the lab. Following the pretest results, we used cookie and strawberry scents as the indulgent and nonindulgent scents, respectively. This ensured that both scents were associated with sweet foods, unlike Study 1a, in which one of the scents (apple) was "sweet" and the other scent (pizza) was "savory." The intensity of the scents, controlled through the scent nebulizer, was kept at the same level for both scents. The two scent conditions were conducted on two different random days, and the lab was well ventilated between each study day.

In the lab, participants were given the option of choosing either strawberries or cookies as their preferred food. We deliberately had food options corresponding to the ambient scents (cookies vs. strawberries) because this gives direct evidence for possible cross-modal and priming effects. Plates of strawberries and cookies, with the lateral positions counterbalanced (Romero and Biswas 2016), were displayed on the table in the lab (for pictures, see Web Appendix B). Participants were told that we were interested in seeing which food item they preferred at that moment. Specifically, we asked participants, "Given a choice between cookies and strawberries, which one would you choose?" We captured this choice using a continuous scale (1 = "definitely cookies," and 7 = "definitely strawberries") as well as a dichotomous choice option.

Results and Discussion

Prolonged exposure to the cookie (vs. strawberry) ambient scent led to greater preference for the healthy option, as revealed by the continuous measure ($F(1, 214) = 5.17$, $p < .05$; see Table 3, Panel B, and Figure 1, Panel B). That is, the cookie (vs. strawberry) ambient scent decreased preference for the indulgent food. For the dichotomous choice measure also, the cookie (vs. strawberry) ambient scent led to reduced choice likelihood for the unhealthy option ($\chi^2 = 4.94, p < .05$). These results again support H_1. Next, Study 2 examines the effects of scents on purchases at a supermarket.

Study 2: Effects of Ambient Scent on Food Sales at a Supermarket

Studies 1a and 1b examined the effects of ambient scent on choices of a single food item in the lab or a limited number of food items in a cafeteria. To enhance the robustness of our findings, Study 2 examined the effects of ambient scent on purchases of multiple items in a retail store, where the items purchased can be healthy, unhealthy, or neutral/nonfood.

Method

Study 2 was a field experiment conducted at a supermarket, in collaboration with the store management. The store is part of a chain of stores in the United States. In line with the recommendation of the store manager, the study was conducted during a random Saturday afternoon, when the store is typically busy, and it is relatively easier to recruit a significant number of participants within a short period of time. The study had two experimental conditions (ambient scent: indulgent vs. nonindulgent). The experimental condition timing was randomly determined. The indulgent scent was chocolate chip cookie and the nonindulgent scent was strawberry. The same type of nebulizer used in Study 1a was used in this study. Both scents were run for approximately an hour each, with an hour's gap in between to let the scent dissipate.

Two research assistants (one female and one male) helped in running this study. One of the assistants set up a table at the entrance of the store next to the area where shoppers get their carts or shopping baskets. The scent nebulizer was placed behind the table, out of view of the customers. During the period of the study, when a shopper approached the shopping cart area, the assistant informed the shopper that (s)he was from a local university, and that as part of a research project (s)he was collecting customer receipts. The assistant informed the customer that all credit card information would be removed from the receipt as that information was not relevant to the project. The assistant also informed the shopper that there was another research assistant standing just outside the store and that if the shopper turned in their shopping receipt to the other assistant upon exiting the store, the shopper would receive a \$10.00 gift card that could be used toward future purchases at the supermarket. The assistant then asked the shopper if (s)he would be willing to turn in his or her receipt at the end of the shopping trip. If the shopper agreed, (s)he was given a sticker and reminded where (s)he could find the other research assistant with the gift cards. Each sticker contained a four-digit number, which served three purposes: (1) a reminder for the participant, (2) an indicator for the assistant standing outside the store, and (3) an indicator of the experimental condition. The recruitment process took approximately two minutes, which ensured that the shoppers were exposed to the scent for an extended duration of time.

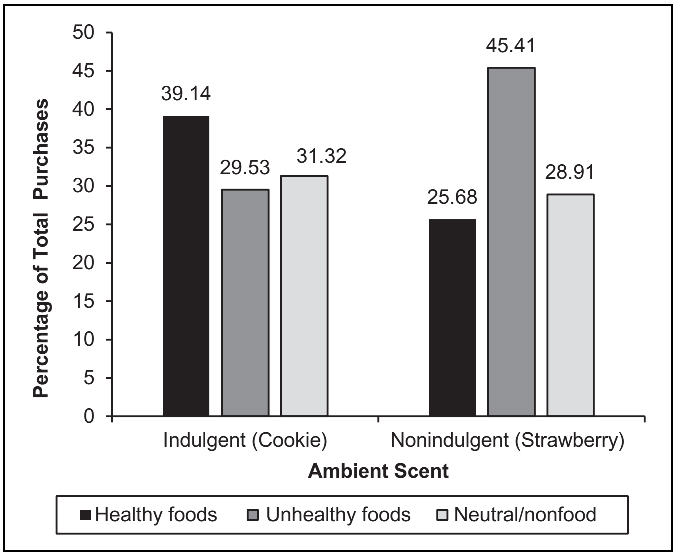


Figure 2. Key results of Study 2.

Customers submitted their receipts to the research assistant at the store exit. We recorded the data for the items purchased and the total bill amounts. The purchased products were coded as healthy, unhealthy, or neutral/nonfood, in line with prior research (Biswas et al. 2017). For example, fruits were coded as healthy, cakes were coded as unhealthy, and paper products were coded as neutral/nonfood items. Appendix A provides the exhaustive list of the different product categories coded as healthy, unhealthy, and neutral/nonfood.

Results and Discussion

The average total number of items purchased per customer was statistically similar for the indulgent versus nonindulgent scent conditions ($F(1, 126) = 1.05, p = .31$), as was the bill total ($F(1, 126) = .94, p = .34$; for cell means, see Table 3, Panel C). Consistent with H_1, the proportion of unhealthy items out of the total number of items purchased, per customer, was lower when there was indulgent (vs. nonindulgent) ambient scent ($F(1, 126) = 6.53, p = .01$). Similarly, the proportion of healthy items out of the total number of items purchased was higher in the indulgent (vs. nonindulgent) scent condition ($F(1, 126) = 4.97, p < .05$). The proportion of neutral/nonfood items out of the total number of items purchased was similar for the two scent conditions ($F(1, 126) = .14, p = .71$; for details, see Table 3, Panel C, and Figure 2). Along with analyzing the data at the customer receipt level, we also analyzed the unhealthy food data in terms of total sales at the aggregate level, similar to the approach used in Study 1a (where we had aggregate sales data only). This analysis again revealed that the proportion of unhealthy items out of the total number of items purchased, was lower when there was indulgent (vs. nonindulgent) ambient scent ($\chi^2 = 25.42, p < .01$).

The results of this field study again demonstrate that extended exposure (for more than two minutes) to an indulgent ambient scent leads to lower level of unhealthy food purchases.

Study 3a: Mediation Effects Tested Through Field Experiment

We tested our proposed mediating effect (i.e., H_2), whereby indulgent food–related ambient scents enhance perceived reward (i.e., pleasantness of the experience) in the reward circuitry of the brain. This, in turn, reduces the preference for unhealthy foods.

Method

Study 3a was a field experiment conducted at the same middle school cafeteria as Study 1a, but on different days. However, whereas Study 1a unobtrusively recorded the children's food purchases from the sales databases, Study 3a involved participants filling out a short survey. The independent variable in the study was the type of food-related ambient scent (indulgent vs. nonindulgent). Cookie and apple (both "sweet") were the indulgent and nonindulgent food–related ambient scents, respectively. The ambient scents were infused in the same way as in Study 1a.

The mediating variable of perceived reward associated with the experience was measured as a composite score of two items (Pearson correlation = .71, $p < .01$), whereby participants were asked to rate the enjoyment (1 = "very low," and 7 = "very high") and pleasantness (1 = "not at all pleasant," and 7 = "very pleasant") of the experience (Elliot and Harackiewicz 1994; Menon and Levitin 2005). Reward value has been measured as subjective pleasantness in prior studies, and subjective pleasantness ratings have been shown to be correlated with reward activation in the brain (e.g., Kringelbach et al. 2003).

The dependent variable was the participating children's food purchases (coded as healthy or unhealthy). As in Study 1a, a trained research assistant, blind to the experimental conditions, coded the food items as healthy versus unhealthy (see Web Appendix C).

About a week before the field experiment was conducted, the children in the middle school (from two different random lunch periods) were given parental consent forms for participating in the field experiment. Those children who turned in the signed parental consent form were allowed to participate in the study. Each participating student received $8 (a $5 gift card for a local store and a $3 cafeteria voucher) as compensation for taking the survey.

Children entered the cafeteria through the main doors and were deliberately slowed down so they would have a prolonged exposure (of more than two minutes) to the scent. The participants received a study survey and were instructed not to complete it until after they had selected their meals. The experiment was between-subjects, whereby children from different lunch groups (but same age/grades) were assigned to the two different scent conditions across the two days.

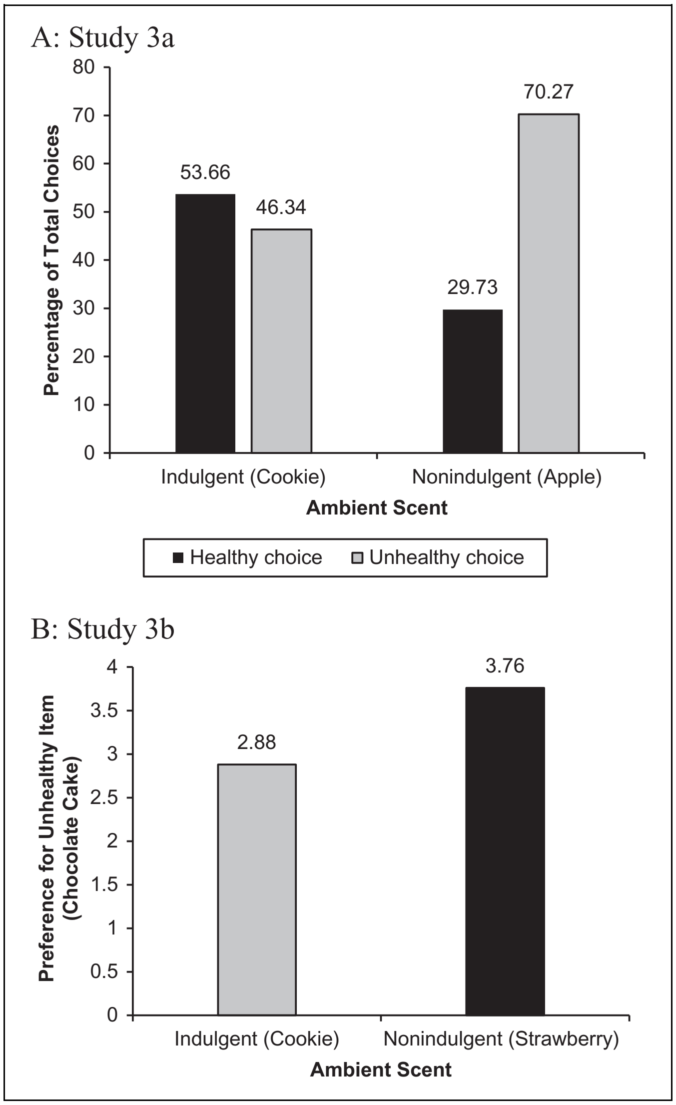


Figure 3. Key results of Study 3.

Results

Main effects. Consistent with H_1, prolonged exposure to the cookie (vs. apple) ambient scent led to lower choice for unhealthy options (Wald $\chi^2 = 4.46$, $p < .05$). In addition, as we predicted, the experience was perceived as more rewarding with the cookie (vs. apple) ambient scent ($F(1, 76) = 5.85$, $p < .05$).

Test of mediation. Mediation analysis using Preacher and Hayes's (2008) bootstrapped samples (5,000) procedure with SPSS PROCESS Model 4 (Hayes 2012) revealed a direct effect of ambient scent on food purchases (B = 1.289, SE = .529, $p < .05$, 95% confidence interval [CI_{95}] = [.2513, 2.3260]) as well as an indirect effect, with the effect being mediated by feelings of having a rewarding experience (B = −.229, SE = .180, $p < .05$, CI_{95} = [−.7824, −.0013]). These results demonstrate a mediation effect because the CI excludes zero, in support of H_2. See also Table 3, Panel D, and Figure 3, Panel A.

Discussion

Study 3a provides support for our theorization about cross-modal sensory compensation effects by demonstrating the mediating role of having a rewarding experience. As theorized, exposure to the indulgent food–related scent enhanced participants' feelings of having a rewarding experience, which presumably satisfied the reward circuitry in the brain and in turn led to reduced desire for unhealthy items. The preference levels for unhealthy foods differed across Studies 1a and 3a, which might be due to several factors, such as the different combination of scents used, students' awareness of study participation approximately a week in advance (in Study 3a), and the monetary compensation for participation (in Study 3a).

Study 3b: Replication of Mediation Effects in Lab Setting

Method, Results, and Discussion

Study 3b was conducted in a lab using a similar procedure to that used in Study 1b. Cookie versus strawberry ambient scents were the indulgent versus nonindulgent scents, respectively. Students from a major U.S. university participated in exchange for course credit. The dependent variable, choice between a fruit salad and a slice of chocolate cake, was measured by asking participants: "Given a choice between a fruit salad and a slice of chocolate cake, which one would you choose?" (1 = "definitely fruit salad," and 7 = "definitely chocolate cake"). The mediating variable of perceived reward associated with the experience was measured by asking the same two questions as in Study 3a (Pearson correlation = .50, $p < .01$).

Main effects. As shown in Table 3, Panel E, and Figure 3, Panel B, the cookie (vs. strawberry) ambient scent was perceived as more rewarding ($F(1, 115) = 4.0$, $p < .05$) and led to lower preference for the unhealthy option ($F(1, 115) = 4.49$, $p < .05$).

Test of mediation. Mediation analysis using Preacher and Hayes's (2008) bootstrapped samples (5,000) procedure with SPSS PROCESS Model 4 (Hayes 2012) revealed an indirect effect, with the effect being mediated by feelings of having a rewarding experience (B = .151, SE = .113, CI_{95} = [.0063, .4873]). These results support H_2 and demonstrate a mediation effect because the CI excludes zero.

Study 4: Moderating Effects of Duration of Exposure

In Studies 1–3, participants were exposed to the ambient scent for an extended duration before they made their purchases or indicated their choices. While in many sales scenarios, customers might be exposed to ambient scents for long periods of time before they make their purchases (e.g., at a supermarket), there can be cases in which the customer is only briefly exposed to the ambient scent (e.g., when walking past a standalone scent-emitting machine or past food court outlets at a mall). In Study 4, we examined if the pattern of results observed in Studies 1–3 might be moderated by the duration of exposure to the ambient scents.

While prolonged exposure to the scents of indulgent foods satisfies cravings for those foods, as argued previously and empirically demonstrated in Studies 1–3, the underlying process differs when there is only brief exposure to the food scents. This is because a brief exposure to food-related scents tends to whet the appetite (Geyskens et al. 2008; Spence 2015). For instance, Seo et al. (2010) found that when participants were exposed to a coffee scent for three seconds, they fixated longer on images of a congruent product (i.e., pictures of coffee) than on images of incongruent products (e.g., milk, beer, wine). Castle, Van Toller, and Milligan (2000) found a similar pattern of results in the context of unpleasant scents when participants were exposed to the scent for four seconds. Rogers and Hill (1989) found that brief exposure to sights and smells of food increases salivation. Sampling (i.e., taking a small bite) of a food high in reward value enhances subsequent consumption of rewarding food items (Wadhwa, Shiv, and Nowlis 2008).

In essence, a brief exposure to a food-related scent will have conceptually similar outcomes as priming effects. That is, being briefly exposed to an indulgent (nonindulgent) food scent would lead to greater likelihood of choosing unhealthy (healthy) foods. So, the effects observed in Studies 1–3 with high duration of exposure should reverse with low duration of exposure to the food-related scents. Formally stated:

> **H_3:** High duration of exposure to an indulgent (vs. a nonindulgent) food–related ambient scent leads to lower choice likelihood of unhealthy foods. In contrast, low duration of exposure to an ambient scent of an indulgent (vs. a nonindulgent) food leads to higher choice likelihood of unhealthy foods.

Method

Study 4 tested H_3 with the help of a 2 (ambient scent: indulgent vs. nonindulgent) × 2 (duration of exposure to scent before making choice: high vs. low) between-subjects experiment. For the first factor, cookie and strawberry scents were used as the indulgent and nonindulgent scents, respectively. The second factor was manipulated by exposing participants to the ambient scent for a prolonged versus brief period before they indicated their food choice. As in our other lab studies, participants first arrived at a waiting area room (which was unscented) and were then brought into a lab (which had ambient scent). In the high-duration conditions, the informed consent script, description of the study procedure, and details about getting the extra credit points were provided to the participants in the scented lab; this procedure took more than two minutes. In the low-duration condition, these details were

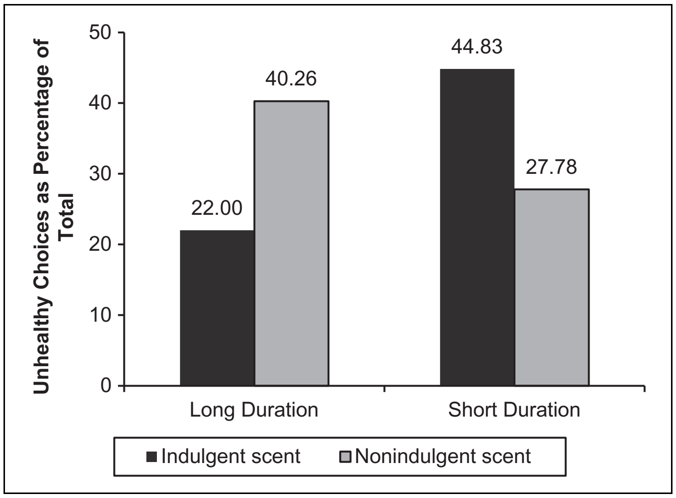


Figure 4. Key results of Study 4.

provided to the participants in the unscented waiting area. That is, in the high-duration condition, participants were exposed to the ambient scent for more than two minutes before they indicated their food choice, while in the low-duration condition, participants were exposed to the ambient scent for less than 30 seconds before they indicated their choice. It should be noted that the overall time spent by participants before the food choice did not vary across conditions—only the amount of time exposed to the ambient scent prior to making the choice varied. The dependent variable was a dichotomous choice between cookies and strawberries.

Results and Discussion

The results of a 2 (scent) $\times$ 2 (duration) logistic regression showed an interaction effect on food choice (Wald $\chi^2 = 8.47$, $p < .01$). Follow-up tests showed that for high duration of exposure to the scents, the pattern of results was similar to that observed in our previous studies. That is, high duration of exposure to the cookie (vs. strawberry) ambient scent led to lower preference for the unhealthy option ($\chi^2 = 4.57$, $p < .05$). The pattern of results reversed in the case of low duration of exposure to the ambient scents. Specifically, low duration of exposure to the cookie (vs. strawberry) scent led to higher preference for the unhealthy option ($\chi^2 = 4.08$, $p < .05$; for cell means, see Table 3, Panel F, and Figure 4). These results, consistent with H_3, suggest a cross-modal sensory compensation effect for high duration of exposure to the scent, with the effects reversing for low duration of exposure to the scent.

Interestingly, for the cookie ambient scent, long (vs. short) duration of exposure led to lower preference for the unhealthy food ($\chi^2 = 6.21$, $p < .05$). In contrast, for the strawberry scent, although the brief (vs. long) duration of exposure led to healthier choices, it was not statistically significant ($\chi^2 = 2.58$, $p = .11$). These results again underscore the dominant role of the indulgent (over the nonindulgent) scent in driving the effects.

Study 5: Effects of Scent Identification Capability

In our prior studies, we focused on the overall effects of ambient scent, without factoring in individual differences in olfactory capability. In the case of olfactory cues, one distinctive point of individual differences relates to the degree of proficiency and capability in identifying scents (Brewer, Brereton, and Tonge 2008). Specifically, individuals differ in terms of olfactory identification capability, with the differences being driven by physiological, neurological, and developmental factors (Bersani et al. 2013). People with higher scent-identification capabilities are more likely to be influenced by scents (Choudhury, Moberg, and Doty 2003). Building on these findings, we predict that the effect of indulgent (vs. nonindulgent) food–related ambient scents will hold for individuals with moderate and high scent-identification capabilities but will be weaker for individuals with low scent-identification capabilities.

> **H_4:** The effects predicted by H_1 for the effects of prolonged exposure to an indulgent (vs. a nonindulgent) food–related ambient scent on food preference hold for consumers with moderate and high scent-identification proficiencies and are weaker for consumers with low scent-identification proficiencies.

Method

Study 5 tested H_4 with the help of an experiment with two factors: ambient scent and scent-identification proficiency. The first factor had three between-subjects conditions (indulgent vs. nonindulgent food–related ambient scents vs. control condition of no scent) and was manipulated in a similar manner as in our other studies, through the use of a nebulizer.

The second factor, scent-identification capability, was measured by administering a University of Pennsylvania Brief Smell Identification Test (UPBSIT) kit (Brewer, Castle, and Pantelis 2006; Doty 2001). The UPBSIT is used for testing general olfactory function, but it can also be used to determine the degree of scent-identification proficiency (Choudhury, Moberg, and Doty 2003), which was the purpose in this study. We used the Quick Smell Identification Test (QSIT) kit, a variant of the UPBSIT, purchased from Sensonics Inc. The test involves identifying three odors (chocolate, banana, and smoke) from a testing kit with scented patches. The number of correctly identified odors serves as the measure of scent-identification capability and is reported as the QSIT (quick smell identification test) score. The QSIT was administered after participants had indicated their food preferences.

The procedure was similar to our other lab studies. Cookie (indulgent) and strawberry (nonindulgent) scents were used as

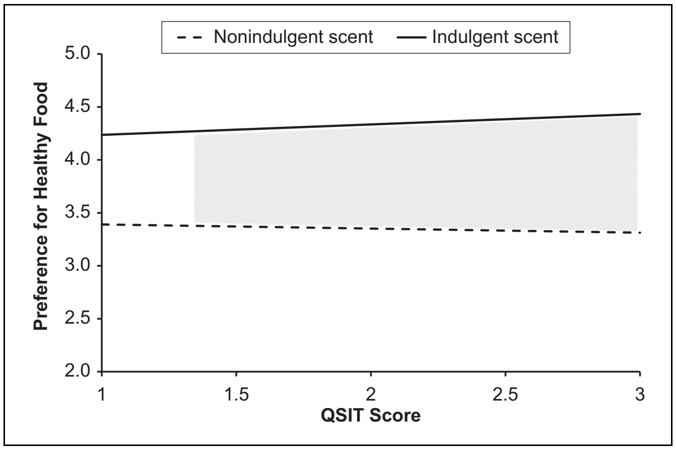


Figure 5. Key results of Study 5.

the ambient scents, and the control condition had no scent. The intensity of the scents was kept at the same level. The three conditions were conducted on three different random days. Participants were asked to indicate (on a 1–7 scale) the extent to which they would prefer a pizza or a salad (where 1 = "definitely pizza," and 7 = "definitely salad"). Participants were exposed to the ambient scent for a prolonged period (of more than two minutes) before they indicated their food choice.

Results and Discussion

Main effect of ambient scent. Consistent with H_1, there was an overall main effect of scent on likelihood of choosing salad versus pizza ($F(2, 169) = 3.20$, $p < .05$). Prolonged exposure to the cookie ambient scent led to higher preference for the healthy (i.e., salad) option than the strawberry scent ($F(1, 170) = 5.19$, $p < .05$) or the no-scent control condition ($F(1, 170) = 4.77$, $p < .05$). In other words, the indulgent (vs. nonindulgent) scent lowered the preference for the unhealthy food option. There was no difference between the strawberry scent and no-scent conditions ($p = .98$; for cell means, see Table 3, Panel G).

Effect of scent-identification capability. We next examined the moderating effect of scent-identification capability. Because the moderator was a cardinal variable, we used the Johnson–Neyman floodlight analysis technique (Spiller et al. 2013) to examine the effects of ambient scent on food choices across the entire range of scent-identification proficiency values. Consistent with recent research (e.g., White et al. 2016), we dummy-coded the focal condition (cookie scent) as 0 and the comparison conditions (strawberry scent and no scent, which had similar effects on food preference) as 1. We used PROCESS Model 1 (Hayes 2013) to run the floodlight analysis. At the 90% CI, the effect of ambient scent on food choice was significant for QSIT values of 1.27 and above; the shaded area of Figure 5 represents the area of significance. The effects are attenuated (at $p > .10$) for QSIT values of below 1.27 ($B = .44$, $SE = .27$; $t = 1.65$, $p = .10$). The overall interaction effect was not significant ($p > .10$), because ambient scent had significant effects on food preference across a wide range of scent-identification capabilities, with the effects becoming attenuated only for participants with low scent-identification capabilities. Specifically, 77.33% of the participants scored higher than 1.27 on the QSIT and had their food choice influenced by the ambient scent, with the effect being attenuated for the 22.67% of participants who scored below 1.27 on the QSIT. These results support H_4.

Notably, as Figure 5 shows, the line for the comparison condition is almost linearly horizontal, implying that the effects of the strawberry scent and no-scent conditions were not influenced by the QSIT score. In contrast, there is an upward-sloping line for the indulgent (cookie) scent. That is, the effects of the indulgent scent on preference for healthy (unhealthy) foods increased (decreased) for participants with higher QSIT scores. These results again highlight that the effects of the ambient scent on food preference are primarily driven by the indulgent scent, consistent with our theorizing and the findings of our other studies.

General Discussion

Theoretical Implications

Whereas prior research has demonstrated interesting cross-modal effects (for examples, see Table 2, Panel A), the present research focuses on cross-modal sensory *compensation* effects. That is, prior research has demonstrated general cross-modal effects, such as, for instance, how strawberry-scented solutions are rated as smelling stronger when colored red than when colorless (see Table 2, Panel A). In contrast, the present research demonstrates cross-modal compensation effects, whereby encountering a cue in one sensory modality (olfaction) can compensate (or satisfy) desires related to another sensory modality (gustatory). This is a novel focus that is underexamined in the literature.

In addition, although prior research has examined different effects and aspects of scents (Krishna, Morrin, and Sayin 2014; Madzharov, Block, and Morrin 2015), the present research is possibly the first to examine the effects of indulgent versus nonindulgent food–related ambient scents on preferences for healthy versus unhealthy food options. That is, this may be the first research to show cross-modal influences of olfactory cues on food choices involving healthy versus unhealthy options. This has important implications for research in the domain of olfaction and sensory marketing in general (Biswas et al. 2014; Krishna 2012).

Overall, the results of three field studies, conducted at a supermarket and a middle school cafeteria, and four studies conducted in the lab demonstrate that extended exposure (of more than two minutes) to an indulgent food–related ambient scent (vs. a nonindulgent scent or no scent) leads to reduced purchase of unhealthy foods. We propose that this occurs because scents related to an indulgent food satisfy the reward circuitry in the brain, which in turn reduces the urge for actual consumption of indulgent foods. We demonstrate the robustness of this phenomenon by examining different sets of indulgent and nonindulgent ambient scents (cookie, pizza, strawberry, and apple), different consumer groups (children and adults), and different settings (supermarket, middle school cafeteria, and lab). We conducted an additional field experiment at a middle school cafeteria to replicate the findings of Study 1a with a la carte menu orders; this study is not reported herein, but we present the statistical results in Table 3, Panel H.

We conducted a single-paper meta-analysis (SPM) to test the reliability of the effects of ambient scent on food choices (McShane and Böckenholt 2017). We included the studies with choice as the outcome variable (i.e., Studies 1a, 1b, 2, 3a, and 4). Studies that had preference as the dependent variable, measured on 1–7 scales (i.e., Studies 3b and 5) were not included in the meta-analysis. The SPM estimates the effects of ambient scent at .1568 (SE = .0114; CI_{95} = [.1345, .1791]). Appendix B provides the plots for the contrasts across the studies. In essence, the results of the SPM suggest that ambient scent related to an indulgent (vs. a nonindulgent) food reduces preference for unhealthy foods by an overall amount of 15.68% (with CI_{95} at 13.45% to 17.91%).

The findings of our research also show the moderating effects of duration of exposure whereby a brief duration of exposure (<30 seconds) led to a reversal of effects. Our findings also highlight how sensitivity to the effects of scents, or scent-identification capability, influences the effects of ambient scent. Consistent with our theorizing, people with higher scent-identification capability are more strongly influenced by the indulgent ambient scent, with the effects being weaker for people with low scent-identification capability.

The focus on children's purchase behavior in two of our field experiments is important, because childhood obesity can be a more serious cause of concern than adult obesity, as it can lead to serious lifelong medical problems including diabetes, heart disease, and even cancer (Weiss, Bremer, and Lustig 2013). Moreover, childhood eating practices often influence lifelong eating behaviors (Birch 1999). Thus, inducing healthful eating during the younger years can have a long-term positive impact. In addition, research on food consumption in marketing literature has primarily focused on adults' choices, with hardly any work examining this in the context of children's food choices; thus, examining children's purchases is novel. While research outside the marketing field has examined children's food consumption and choices, the foci of these research streams have been different from what we study (see Table 2, Panel D).

It is also worth noting that school cafeterias offer a unique opportunity to examine children's independent ordering and purchasing behaviors, because, in most other shopping contexts, children's purchases are directly influenced by adults. In addition, two of our field studies were conducted in a cafeteria located in a neighborhood with a high proportion of low-income, working-class people. Most studies in marketing and in other social sciences tend to examine the behaviors of middle-class U.S. consumers; the behaviors of working-class consumers are often ignored in marketing studies (Pham 2016). Thus, it is relevant to have participant samples that explicitly include these groups in field settings.

In terms of consumer well-being, the findings of our research have strong implications for food cravings and obesity. In essence, if reward structures and areas representing craving in the brain can be satisfied with olfactory inputs instead of actual gustatory consumption of unhealthy foods, this can help with fighting food urges. One important takeaway from this research is that having extended exposure to ambient scents of indulgent foods (e.g., cookies) can paradoxically reduce preference for unhealthy foods.

Managerial Implications

As outlined in Table 1, retail stores, restaurants, hotels, airplanes, and even stadiums and indoor arenas are increasingly using ambient scents, with food-related scents becoming quite prevalent. Interestingly, the results of our field studies show that using a cookie or pizza ambient scent leads to relatively greater sales of healthier items. Thus, a supermarket or a restaurant wanting to sell more healthy items (perhaps because of brand associations or higher margins) might want to have ambient scents related to indulgent or "rewarding" foods, such as cookies or pizza (see, e.g., our Study 2 results).

The duration of exposure (e.g., Study 4) also matters. Thus, Hard Rock Hotel's strategy of giving customers a whiff of cookie and waffle scent at the top and bottom of a staircase to increase sales of ice cream makes sense, because customers are exposed to the scents for only a brief period (see Table 1). Retail stores can place scent nebulizers strategically to optimize the duration of exposure to the scent. For example, a supermarket can place cookie ambient scent nebulizers in a continuous manner near the fresh produce section, ensuring prolonged exposure to the scent. In contrast, to enhance the sales of cookies, cakes, and chocolates, the scent nebulizers can be placed at the point of entrance, providing only a brief duration of exposure to the cookie ambient scent. Similarly, for a fast-food restaurant, where customers would be exposed to the ambient scent for only a brief period before placing their orders, use of indulgent food scents would spur sales of high-calorie foods. In contrast, for a sit-down restaurant, where customers would be exposed to a scent for a prolonged period before placing their orders, use of indulgent food scents can spur increased ordering of healthy foods.

There are also direct practical implications for home scent management. For example, Glade now manufactures cupcake-scented and cookie-scented air fresheners, and several companies are selling different types of cookie-scented room sprays. If the findings of our research hold in nonstore, noncafeteria, and nonlab settings, such as in homes, then using cookie-scented air fresheners or scented candles could possibly nudge healthier choices at home. Clearly, additional research in home settings is needed to explore this in greater depth.

Limitations and Future Research Directions

We primarily focused on managerially relevant outcomes, such as actual food purchases and choices. While we examined the process through tests of mediation, additional studies are needed to examine the underlying process in greater depth. Furthermore, research is needed to examine the inflection point between "extended" versus "brief" durations of exposure to ambient scents that lead to sensory compensation versus priming consistent effects. Additional research is also needed to examine how long the effects of indulgent olfactory cues would curb cravings for indulgent foods.

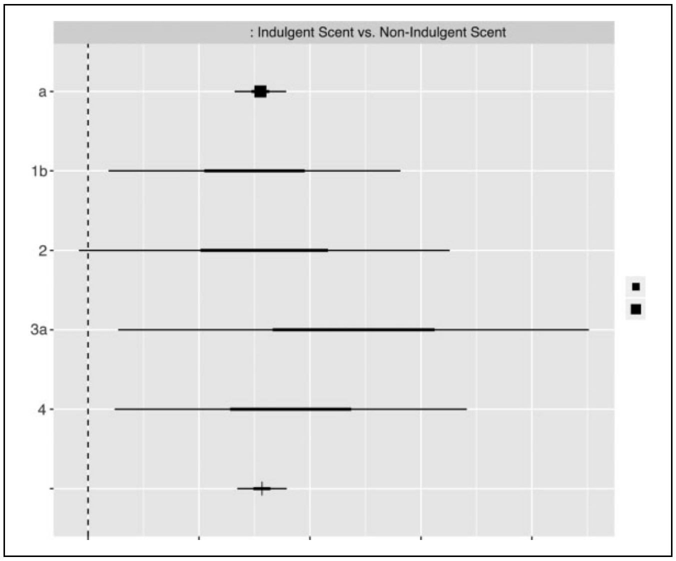
Notably, prior research on the effects of emotion on indulgent consumption has shown mixed results, with some studies finding that positive (negative) emotions lead to higher (lower) indulgence and others showing an opposite pattern of effects (for details, see Table 2, Panel C). Future research needs to resolve this apparent inconsistency and link this literature stream with the positive rewarding experience induced by ambient scents.

In this research, we focused on the effects of ambient scent; however, retail managers can manipulate several other ambient factors, such as music or lighting (Biswas et al. 2017). How might ambient scent interact with ambient light or music to influence purchases? There is scope for promising research in the area of cross-modal interactions between different ambient sensory stimuli. Indeed, given the limited research on cross-modal sensory compensation effects of sensory cues, there is scope for substantial work in this domain. We hope our research will encourage significant work in this and related areas.

Appendix A: Product Category Codings for Study 2

Product Categories Coded as "**Healthy Items**"	Product Categories Coded as "**Unhealthy Items**"	Product Categories Coded as "**Neutral/Non-Foods**"
- Coconut water	- Cakes	- Alcoholic beverages (e.g., beer, liquor, wine)
- Eggs and egg whites	- Cheese breads and bread sticks	- Baking soda
- Fish (e.g., salmon)	- Chips	- Barbeque sauce
- Fresh herbs	- Chocolates and candies	- Broth
- Fruits (e.g., apple, banana, pineapple, strawberry)	- Cookies	- Cigarettes
- Kombucha	- Creamy dressing	- Cleaning products
- Low-fat milk	- Croutons	- Coffee
- Nuts	- Dips	- Cooking oil
- Rice	- Donuts	- Cosmetics
- Vegetables (e.g., cabbage, carrots, kale, peas, spinach)	- Fried food	- Flour
- White meat (e.g., chicken)	- Frozen potato fries	- Flowers
- Yogurt	- Full-fat milk	- Greeting cards
	- Ice creams	- Ground spices
	- Lasagna	- Gum
	- Lemonade	- Ice
	- Mac and cheese	- Lottery tickets
	- Pizza	- Medicine
	- Popcorn	- Newspaper
	- Processed meats	- Paper products (e.g., toilet tissue, paper towels)
	- Pre-made deli sandwiches	- Pet foods
	- Red meat (e.g., beef, pork,)	- Toothpaste/toothbrush
	- Soda	- Water products (e.g., flavored water, tonic water)
	- Sports drinks (e.g., Gatorade)	
	- Snack mixes (e.g., Chex mix)	
	- Taco shells	

Appendix B: Single-Paper Metaanalysis for Effects of Ambient Scent on Food Choices Across Studies 1A, 1B, 2, 3A, and 4



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