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Multisensory Marketing: Effects of Environmental Aroma Cues on Perception, Appetite, and Consumption of Foods and Drinks

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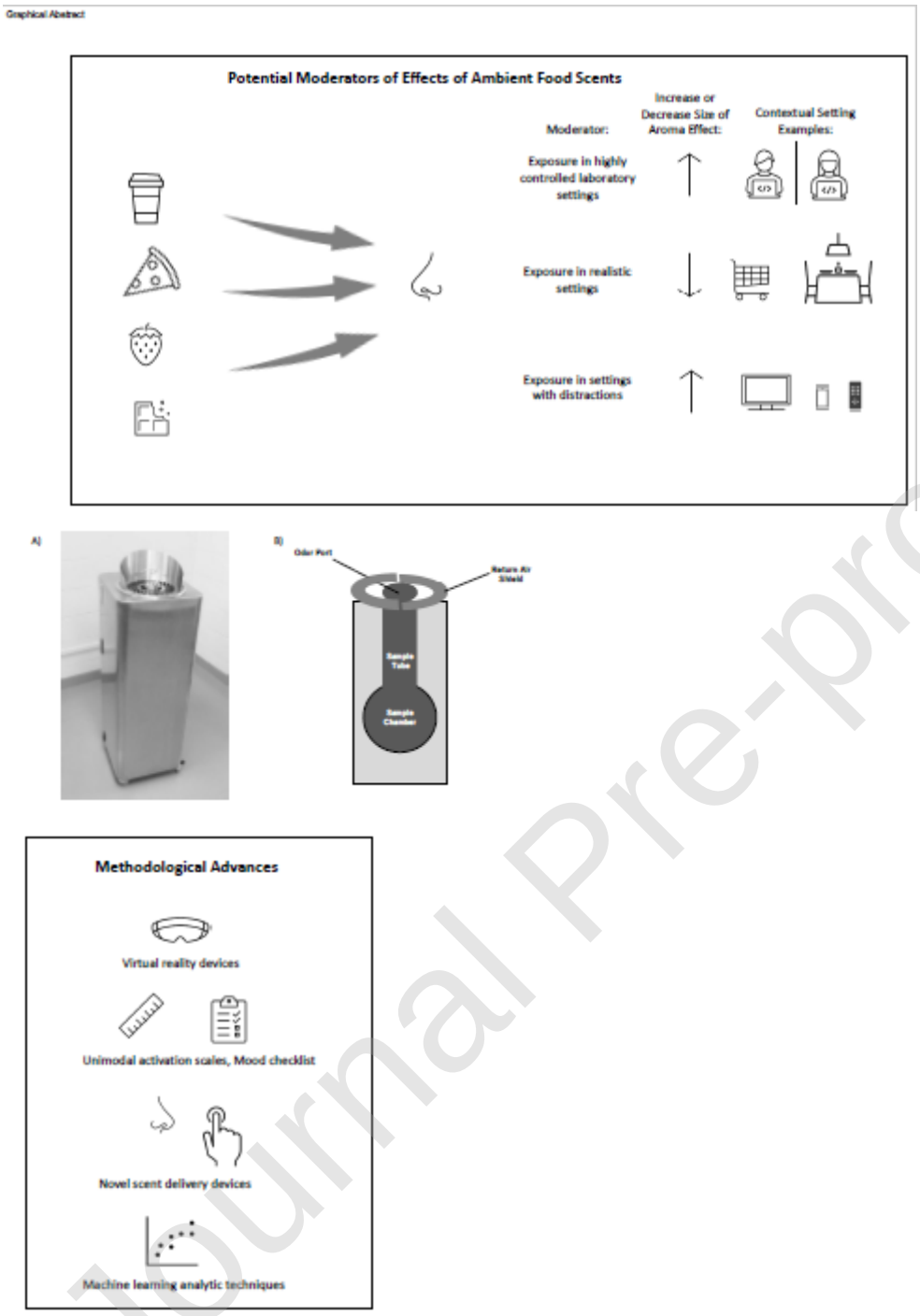
Graphical abstract



Highlights

- The extent to which aromas alter appetite or food choice may vary by situational context (e.g., laboratory versus field settings) and delivery method (e.g., length and intensity of aroma exposure).

- There has been a shift in sensory research to incorporate more realistic contexts including virtual reality.
- The use of novel aromatizing devices and data analytic tools have been introduced which may facilitate the field's ability to more accurately predict consumer response to aromas.

Abstract

We review recent research on the effects of food and beverage aromas on appetite and consumption. The results are mixed, suggesting that the size and direction of effects may depend on contextual factors such as laboratory versus field setting, length and intensity of aroma exposure, etc. Our review also documents an increasing tendency toward conducting sensory research in contexts that incorporate more realism, either through the use of field settings or technology such as virtual reality headsets. We also note several recent methodological advances likely to enhance the field's ability to accurately predict the effect of aromas on human behavior.

Keywords: Aroma; scent; consumption; appetite; multisensory; marketing; mindset; Virtual reality; field studies; context

Introduction

We review recent theoretical and methodological advances regarding research on the effect of exposure to various ambient food and beverage aromas on behavior. We focus primarily on articles published within the last two years (i.e., 2018 to 2020) as well as representative earlier publications from the fields of sensory science, appetite, food choice, and marketing. Findings suggest that contextual elements, such as whether studies are conducted in highly controlled laboratory environments versus more real-world settings, may moderate the extent to which aromas impact appetite, consumption, and purchase behavior. Further, the length, type and strength of aroma exposure, as well as conscious awareness of aromas and distractions in the

environment can impact outcomes. We also discuss recent advances in methods of delivering, measuring, and empirically analyzing the effects of ambient aromas, which may facilitate sensory researchers' ability to more accurately predict the effects of aromas.

Effect of Ambient Aroma on Perceptions of Proximity to Source Object

We learn over time that when we smell an aroma, it is being emitted from a specific, nearby source object. We thereby come to associate aromas with their sources, namely, the object(s) that emit them. The smell of apple pie or chocolate chip cookies detected during the baking process brings to mind the aromas' sources – apple pies and cookies (see [1] for a recent meta-analysis of consumer response to pleasant ambient odors)

Recent research on the effects of exposure to aromas underscores their role in triggering semantic associations with the aromas' sources, and how these learned associations impact subsequent consumption behavior. For example, scented advertisements induce a feeling of being within close proximity to the advertised product, driving increased product appeal [2]. Although these studies were conducted with personal care products such as candles and soaps, the results may extend to foods and beverages.

A critically important question for the nutrition community and the hospitality industry is whether ambient food aromas act as cues to alter appetite, food choice, or energy consumption. Most of us have experienced shopping in a mall and smelling the tempting

aroma of cinnamon buns wafting through the air. Conventional wisdom and prior research suggest that smelling enticing aromas of appetizing foods and beverages enhances the desire for, probability of purchasing, and consumption of such foods.

Recent research suggests potential boundary conditions for such effects, however (Figure 1). The effect of enticing food aromas may depend on whether such effects are measured in a highly controlled laboratory setting versus more realistic settings -- whether virtual, simulated, or field study environments such as coffeeshops and grocery stores, for example.

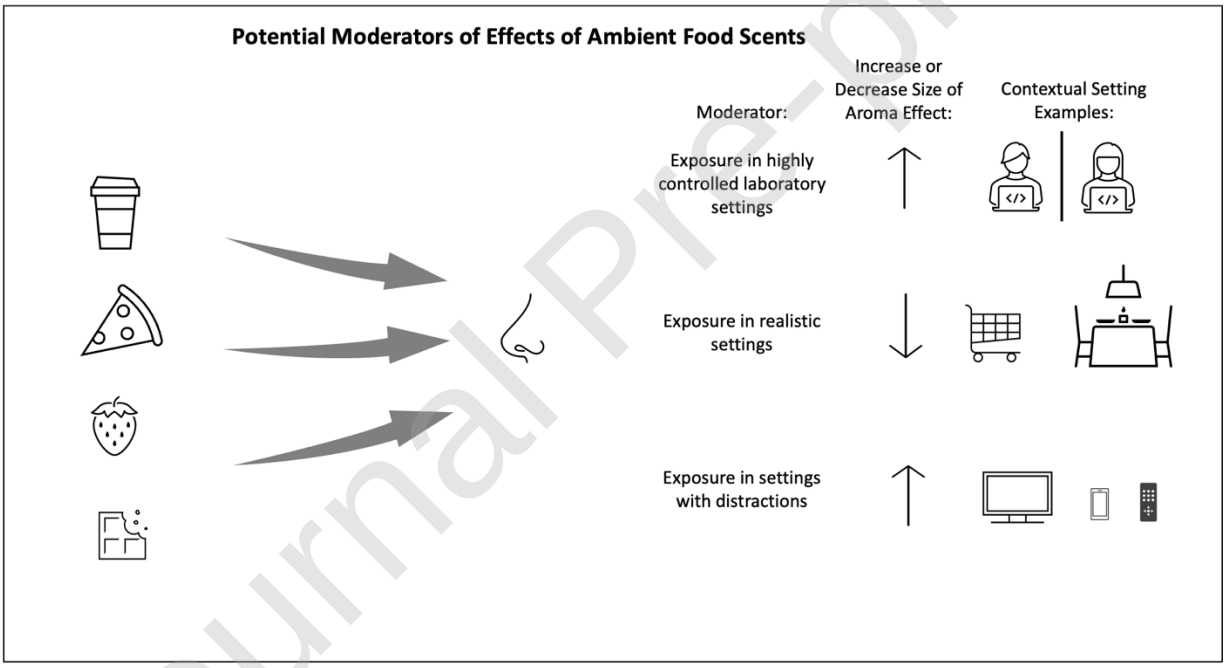


Figure 1. Moderating Impact of Contextual Factors on Aroma Effects Evident in Recent Research

Effect of Aroma Exposure on Appetite and Food Selection

We first discuss studies addressing the impact of ambient aromas on appetite and food intake. These studies generally fit into three categories: those measuring the effects of aromas on selection of meal items from a menu; reported appetite or desire to consume particular foods from a list; or ad-libitum food intake in a laboratory or cafeteria setting.

Menu Selection Studies

Gaillet et al. [3] examined the priming effects of fruit aromas on the selection of menu items for a multi-course meal and is representative of studies with this focus. In two separate experiments, male and female participants were exposed for 10 minutes to undetectable melon aroma or no aroma (experiment 1) or to undetectable pear aroma or no aroma (experiment 2) and were asked to choose food items for a (hypothetical) multi-course lunch. Aromas were diffused into ambient air using a vaporizer. Exposure to melon (vs. no) aroma led to greater selection of a vegetable starter (appetizer), whereas exposure to pear (vs. no) aroma led to greater selection of fruit desserts.

Questionnaire Studies

Several studies use questionnaires to examine the effects of food aromas on self-reported appetite (i.e., desire to consume the food at that point in time). A key objective of these studies is to disentangle the extent to which sensory quality (sweet or savory) and energy density interact in the priming effect of aromas on appetite ratings. In one study with healthy-

weight women, Ramaekers et al. [4] administered sweet or savory aromas associated with either high-energy density (HED) or low-energy-density (LED) foods. Chocolate and banana aromas represented HED and LED sweet foods, respectively; meat and tomato soup aromas represented HED and LED savory foods, respectively. Noticeable aromas were diffused into the ambient air for 20 minutes using a vaporizer. Sweet aromas enhanced appetite for sweet foods and savory aromas enhanced appetite for savory food, but no energy density-specific effects were observed.

Zoon et al. [5] came to a similar conclusion in a study among healthy-weight women using chocolate, beef, melon, cucumber and fresh, grassy green (i.e., non-food) aromas delivered via sniff jars. Sweet (savory) aromas increased the general appetite for sweet (savory) foods, regardless of the energy density of the foods.

Food Selection and Intake Studies

Several laboratory feeding studies examined the role of HED and LED sweet and savory aromas on food intake, with mixed results. One study among healthy-weight women Proserpio et al. [6] showed that HED aromas (chocolate or beef) increased ad-libitum intake from a test meal of chocolate-flavored rice, but LED aromas (melon or cucumber) did not enhance intake. Aromas in this study were diffused into the air with a vaporizer for 30 minutes at mild but detectable levels.

In an earlier report, Zoon et al. [7] exposed heathy-weight and over-weight women to HED and LED sweet and savory aromas (chocolate, strawberry, melon, cucumber) and measured food intake from a bogus taste test in which participants sampled chocolate paste, peanut butter, strawberry jam, and cucumber salad on crackers surreptitiously weighed before and after the test. The aromas were diffused into the air for 20 minutes at mild but detectable levels. Tests were conducted in both hungry and satiated states. Although energy intake was higher in the hungry versus satiated state, no effects of the aromas were observed on energy intake or food selection.

Another study [8] investigated the effects of aroma priming on macronutrient selection (e.g., chicken aroma for proteins, butter aroma for fats, etc.) using recognizable aromas sniffed from jars. No macronutrient effects were observed on food intake. Another study [9] examined the effects of bread aromas (vs. no aroma) on ad-libitum consumption of zucchini/potato soup in women with obesity. Noticeable but mild aromas were diffused with a vaporizer for 10 minutes. Bread (vs. no) aroma increased consumption of soup. The women reported highest appetite for HED-savory foods and lowest appetite for LED-sweet foods.

A study by Mors et al. [10] is distinct among these studies in that it examined food selection in a realistic setting outside the laboratory. Male and female participants (of undefined weight status) were exposed to bread or cucumber aroma diffused for 20 minutes at non-noticeable concentrations in a restaurant. Food selection from a buffet lunch was measured. However, no effects of the aromas were observed.

Critique

A range of conditions that have been tried appear to be sufficient to product a response on appetite or consumption. But the results across these studies are mixed. Aroma exposure in some studies influenced what participants ate (or intended to eat) but not necessarily how much they ate. It is difficult to summarize the priming effects of aromas on the selection or intake of HED or LED foods. Two studies [4, 5] showed only general effects of sweet or savory aromas on appetite for foods with similar sensory qualities. One study [7] showed some evidence for HED-associated aromas guiding laboratory intake of an HED test food, but another study [5] failed to show this relationship in a food selection task. The mixed results may be due to methodological differences, such as how the aromas were emitted or due to differences in exposure time or intensity. Given the limited extant literature in this area and the fact that the majority of studies were conducted in healthy-weight women, more work needs to be done to understand the effects of aromas on food selection and eating behavior across all weight groups and in both genders.

Studies from the Marketing Literature

Recent research in marketing examined the role of indulgent vs. non-indulgent aromas on purchasing behavior in realistic environments. One study [11] in a middle school cafeteria compared the effect of 2-minute exposure to an indulgent aroma (pizza aroma), a non-

indulgent aroma (apple aroma), or no aroma on students' food choices, which were classified as 'healthy' or 'unhealthy'. A lower proportion of students' purchases consisted of unhealthy items (21.43%) after exposure to the more indulgent pizza aroma (versus 36.96% in the apple aroma condition and 36.54% in the no aroma control). Similar results emerged from a field study in a supermarket [11]. The authors suggest longer exposure (e.g., > 2 minutes) to indulgent food aromas may impact the reward circuitry of the brain, which compensates for actual food consumption. Length of aroma exposure in these studies was shorter than that in the appetite and food choice studies, with its potential effect on results unknown. This issue deserves further attention.

Distractions Reduce Awareness of Ambient Aroma

Another focus of recent research examines the role of scent awareness on response [12]. If people are distracted by input from other sensory modalities, they may not notice aromas present in the environment. For example, one study [13] showed that when people were engaged in a visual search task that exerted a high perceptual load on mental processing, they were less likely to notice the presence of an ambient coffee aroma. Lack of conscious awareness of an aroma, referred to as *inattentional anosmia* [13], does not imply that it will not have an impact on response, however.

Although it is possible that an unnoticed aroma will have no effect on an individual, another possibility is that an unnoticed aroma may have a greater effect on an individual than one that

is consciously processed [14]. When individuals are unaware of the potential influence of nonconscious cues or primes, they are unable to cognitively control for them [15]. As a result, aromas emitted into retail settings designed to elicit positive consumer responses may have an effect even if emitted at very low levels of intensity or when consumers in such settings are simultaneously distracted by other sensory inputs or mental activities.

Reduced attention to or conscious awareness of ambient aromas may help to explain why individuals who eat while visually or otherwise engaged in distracting activities such as watching TV or texting, may overconsume [16]. Spence [12] proposes that researchers interested in understanding the overconsumption of food and drink consider the role of attentional distraction from the senses of smell and taste. A related stream of research [17] suggests that even when individuals do detect aromas, they sometimes attribute them to experiences from other senses such as vision or hearing. It is therefore possible that exposure to aroma that is misattributed to other sensory experiences may have larger effects on consumption than those that are correctly attributed to olfactory experiences.

Recent Methodological Advances in Aroma Research

We next discuss advances in aroma research related to methodologies, such as measurement scales and devices for delivering or virtually experiencing sensory inputs.

Advances in Measuring the Emotional Impact of Aroma

It has long been thought that aromas differ not only in valence, or liking, but also in terms of their activating quality. Mint and citrus aromas, for example, are often rated as stimulating, whereas lavender and vanilla aromas are often rated as relaxing [18]. A recent Implicit Association Test supports the existence of associations between relaxing words (such as relaxed, soothed, serene, etc.) with the aroma label "vanilla," and energizing words (such as revitalized, invigorated, energetic, etc.) with the aroma label "mint" [18].

The extent to which an aroma is perceived to be stimulating is often measured using bidimensional scale items, such as semantic differentials, which suggest that if an aroma is stimulating it must necessarily be less relaxing. Challenging this notion, one study [19] examined the activation properties of several odorants at different concentration levels using separate rating scales for relaxing and stimulating. The intensity of two aromas previously identified as relaxing were tested: strawberry and lavender, and two aromas previously identified as stimulating: coffee and lemon, at five different concentration levels. Somewhat surprisingly, the authors found that increasing concentrations of strawberry and lavender led to marginally higher relaxing *and* stimulating ratings. In contrast, increasing coffee and lemon aromas led to a robust reversal in the ratings from relaxing to stimulating. The results for lemon are consistent with prior research [20] which used a check box technique to assess emotion (e.g., pleasant, stressed, angry, etc.).

Increased Use of Virtual Reality Devices to Simulate Sensory Experience

Although some researchers conduct field studies to test the real-world effects of ambient aromas on individuals' responses, others are utilizing technological advances in the form of virtual reality devices. Virtual reality and simulated environments are increasingly popular modes for assessing consumer reactions in far more naturalistic settings than can be achieved in the laboratory or testing booth. Simulated environments can immerse participants in the sights and sounds of a cafeteria, coffee shop etc., but they rarely include ambient aromas [21]. In an earlier study [22] consumers were more discriminating of sensory differences in coffee samples when they rated them in a virtual coffeehouse providing visual, auditory and aroma cues (ambient cinnamon roll aroma) than when they rated the same samples in a laboratory setting. In a more recent study [23], participants ate a buffet lunch in a simulated natural environment with bird songs, a forest landscape and ambient orange aroma or a standard laboratory setting. No differences in food intake were found between the two conditions, but participants exhibited higher positive emotions in the natural environment.

Although the unique effects of ambient aromas cannot be parsed out in these studies, it seems reasonable to assume that including olfactory cues in a simulated environment would create a more authentic multisensory experience than when such cues are absent.

Development of Novel Devices for Aroma Delivery

Vaporizers are the primary method for aromatizing ambient air in sensory perception and food behavior studies, although sniff jars have also been used, to a lesser degree. The two methods

exert different attentional and operator demands on participants. When vaporizers are used, participants passively experience aromas dispersed in the air and may or may not be aware of their presence. In the case of sniff jars, participants must self-administer the samples, heightening their expectations and conscious awareness of the aroma. The impact of these methodological features on study outcomes is presently unknown. Also, with vaporizers, typically just one room or environment can be aromatized at one time. In large, between-subjects studies testing multiple aromas, researchers may be limited to testing a relatively small number of aroma conditions. On the other hand, a major shortcoming of sniff jars is controlling the release of aromas from headspace into the surrounding air when the cover is removed for evaluation.

The portable olfactive device (qPOD; Curion Insights, Dearfield, IL) offers another alternative. The qPOD is a recently developed aroma delivery device that releases a constant stream of aromatized air to a single participant through a port at the top of the machine (see Figure 2). The air is drawn back into the device through a carbon filter, purging the surrounding air of the aroma. When compared to sniff jars, the qPOD produced similar hedonic and emotional reactions to common aromas [24]. Intensity ratings were higher with sniff jars than with the qPOD, likely reflecting differences in airflow between the two methods. The qPOD depends on dynamic airflow whereas volatiles accumulate in the static headspace of the sniff jars.

Since qPODs deliver a more controlled aroma experience without the need to diffuse an entire room with an aroma, several qPODs can be placed in the same room allowing participants to

sample several different aromas in the same test session. The qPOD could also be a convenient method for studying whether aromas experienced orthonasally (i.e., sniffed through the nose) while a food sample is tasted by-mouth.

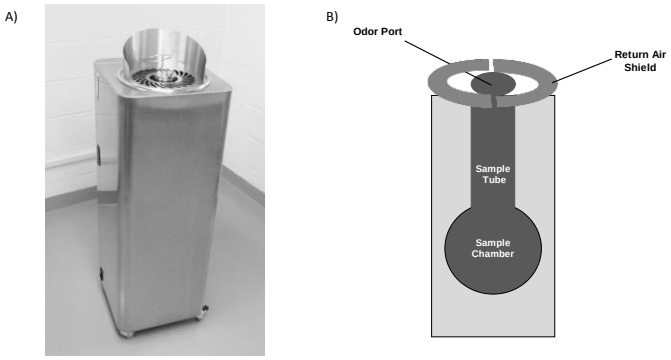


Figure 2. The qPOD Aroma Delivery Device

Advances in Aroma Detection Technology and Data Analytic Techniques

The electronic nose (or eNose) is an analytical tool widely used in the food industry to monitor authenticity of raw materials, processing conditions, quality and freshness. Typical applications include rapid identification of pathogens, spoilage molecules and adulterants [25]. The eNose utilizes a gas sensor array to generate complex volatile profiles that are interpreted using a range of pattern recognition algorithms and classification procedures. Several recent studies have added machine learning techniques to the data obtained from an electronic nose to more accurately simulate the human sense of smell. For example, Muller et al. [26] used K nearest neighbors to classify aromas based on their ion-mobility spectrometry measurements from an eNose. Men et al. [27] incorporated random forests and probabilistic neural networks to

construct aroma fingerprints of different brands of liquor from a lab-developed artificial nose, in an attempt to simulate human olfaction. Although studies designed to link eNose profiles with human sensory experiences have been reported in the literature [28], our understanding of these relationships remains limited. Advances in sensor arrays (e.g., nano-sensors) that better emulate the broad capabilities the human olfactory system will accelerate progress in this field.

Machine learning techniques represent a powerful set of tools to mine complex sensory data sets. For example, Nozaki and Nakamoto [29] combined machine learning with natural language processing (to cluster verbal descriptors) to analyze aromas. Such innovative analytic techniques move beyond traditional statistical methods such as principal components and regression [30]. Machine learning techniques such as decision trees with bootstrapping components have also been used to structure sensory descriptors for food items, such as wine aroma and off-odor terms, into hierarchical lexicons [31]. Such techniques could potentially be used to analyze other types of unstructured sensory consumer data in future research efforts. Methodological advances are depicted in Figure 3.

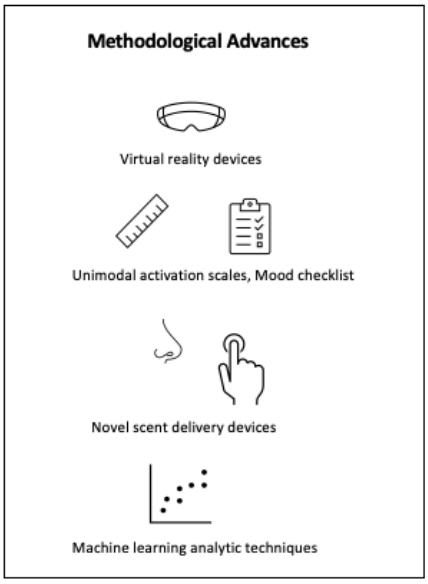


Figure 3. Some Recent Methodological Advances

Conclusions

The traditional approach to sensory research relies upon highly standardized testing methodologies to precisely measure differences between products. Traditionally, participants are seated in individual booths, devoid of extraneous sights, sounds, and smells. Trained sensory panelists are often utilized, in order to obtain objective ratings. Even when naïve or untrained consumer participants are utilized, these sterile environments do not represent how most people actually taste, eat, and drink in the real world. Sensory testing efforts have therefore begun to shift toward utilizing more real-world testing environments including restaurants, stores, and homes, as well virtual reality devices or physical spaces constructed to mimic real-world consumption settings. The use of virtual coffee shops or pub houses to assess

beverage consumption in contexts that look, feel, and smell like the "real thing" are likely to uncover results that better predict real world behaviors. Although the testing booth is not going away, its results will be complemented and our understanding of consumer response to aromas enhanced by studies conducted in more realistic environments.

We speculate that participants in aroma studies may approach their tasks with different types of mindsets [32] in these different settings. Those in highly controlled laboratory settings may approach a product or sensory evaluation task with a mindset highly focused on the task at hand. As such, they may be highly conscious of very minor differences in sensory characteristics. Participants in more realistic settings, in contrast, may approach the task with a mindset less squarely focused on the task at hand, allowing their attention to be drawn to various other stimuli to which they are simultaneously exposed (other sights, sounds, smells, etc.). Additional research is needed to determine under what conditions the effects of aromas are strengthened versus weakened by the presence of a multitude of other stimulus cues typically present in real-world settings.

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Declaration of Interest: None.

Bibliography

1. Roschk H, Hosseinpour M: **Pleasant ambient aromas: A meta-analysis of customer responses and situational contingencies**. *Journal of Marketing* 2020, **84:** 125-145.

2. Ruzeviciute RKamleitner B, Biswas D.: **Designed to s(m)ell: When aromaed advertising induces proximity and enhances appeal.** *J Marketing Research,* 2020, **57**:315-331.

3. Gaillet M, Sulmont-Rossé C, Issanchou S, Chabanet C, Chambaron S: **Priming effects of an olfactory food cue on subsequent food-related behaviour** 2013, *Food Quality and Preference,* **30**:274-281.

4. Ramaekers MG, Boesveldt S, Lakemond CMM, van Boekel MAJS, Luning PA: **Odors: appetizing or satiating? Development of appetite during odor exposure over time.** *International Journal of Obesity* 2014, **38***:*650-656.

5. Zoon HFA, de Graaf C, Boesveldt S: **Food odours direct specific appetite.** *Foods* 2016, **5**:12.

6. Proserpio C, de Graaf C, Laureati M, Pagliarini E, Boesveldt S.*:* **The impact of ambient odors on food intake, saliva production and appetite ratings.** *Physiology & Behavior* 2017, **174***:*35-41.

7. Zoon HFA, de Graaf C, Laureati M, Pagliarini E, Boesveldt S.: **Food preference and intake in response to ambient odours in overweight and normal-weight females.** *Physiology & Behavior* 2014, **133**:190-196.

8.Morquecho-Campos P, de Graaf K, Boesveldt S: **Smelling our appetite? The influence of food odors on congruent appetite, food preferences and intake.** *Food Quality and Preference* 2020, **85**:103959.

9. Proserpio C, Invitti C, Boesveldt S, Pasqualinotto L, Laureati M, Cattaneo C, Pagliarini E.*:* **Ambient odor exposure affects food intake and sensory specific appetite in obese women.** *Frontiers in Psychology* 2019, **10***:*7.

** 'Externality', or increased responsiveness to food cues (i.e., the sight, smell and taste of food) is a common feature of obesity. This study reported that ambient bread aroma increased reported appetite for high energy-density savory foods relative to low-energy density sweet foods in women with obesity. The no aroma condition did not alter sensory-specific appetite. These findings are similar to those observed in earlier studies in healthy-weight women.

10.Mors MR, Polet IA, Vingerhoeds MH, Perez-Cueto FJA, de Wijk RA.: **Can food choice be influenced by priming with food odours?** *Food Quality and Preference* 2018, **66**:148-152.

11. Biswas D, Szocs C.: **The smell of healthy choices: Cross-modal sensory compensation effects of ambient aroma on food purchases.** *Journal of Marketing Research* 2018, **56**:123-141.

** Highlights the impact of short and long exposure to food odors on amount consumed.

12. Spence C.: **Attending to the chemical senses.** *Multisensory Research* 2019, **32**:635-664.

** Attentional selection plays a role in chemosensory processing, although this issue to date has received little attention from experimental psychologists and cognitive neuroscientists. Attentional distraction can occur when eating while watching television, for example. Paying less attention to aromas of foods and beverages during consumption may have important consequences for the amount consumers eat and drink.

13. Forster S, Spence C.: **What smell? Temporarily loading visual attention induces a prolonged loss of olfactory awareness.** *Psychological Science* 2018, **29**:1642-1652.

14. Prasad S, Mishra RK: **The nature of unconscious attention to subliminal cues**. *Vision* 2019, **3**:38.
15. Papies EK: **Goal priming as a situated intervention tool.** *Current Opinion in Psychology* 2016, **12:**12-16.
16. Ogden J, Coop N, Cousins C, Crump R, Field L, Hughes S, Woodger N: **Distraction, the desire to eat and food intake: towards an expanded model of mindless eating.** *Appetite* 2016, **62**: 12-16.
17. Spence C, Obrist M, Velasco C, Ranasinghe N: *Digitizing the chemical senses: Possibilities & pitfalls. International Journal of Human-Computer Studies* 2017, **107**:62-74.
18. Lemercier-Talbot A, Coppin G, Cereghetti D, Porcherot C, Cayeux I, Delplanque S.: **Measuring automatic associations between relaxing/energizing feelings and odors**. *Food Quality and Preference* 2019, **77**:21-31.
19. Baccarani A, Brand G, Dacremont C, Valentin D, Brochard R: **The influence of stimulus concentration and odor intensity on relaxing and stimulating perceived properties of odors.** *Food Quality and Preference* 2021 forthcoming.
20. Jin L, Haviland-Jones J, Simon JE, Tepper BJ: **Influence of aroma intensity and nasal pungency on the 'Mood Signature' of common aroma compounds in a mixed ethnic population.** *Food Quality and Preference,* 2018, **65**:164-174.
21. Porcherot C, Delplanque S, Gaudreau N, Ischer M, De Marles A, Cayeux I**: Immersive techniques and virtual reality.** *Varela P Ares G. Methods in consumer research: Alternative approaches and special applications. New York : Elsevier Science and Technology, 2018,* **2**:69-80.
** Comprehensive review on simulated environments.
22. Bangcuyo RG, Smith KJ, Zumach JL, Pierce AM, Guttman GA, Simons, CT: **The use of immersive technologies to improve consumer testing: The role of ecological validity, context, and engagement in evaluating coffee.** *Food Quality and Preference,* 2015, **41**:84-95.
23. Hoppu U, Puputti S, Mattila S, Puurtinen M, Sandell M: **Food consumption and emotions at a salad lunch buffet in a multisensory environment.** *Foods* 2020, **9**:1349.
24. Gaby JM, Tepper BJ: **A comparison of hedonic and emotional responses to common odors delivered by qPODs (Portable Olfactive Devices) and traditional sniff jars.** *Food Quality and Preference* 2020, **80**:103804.
25. Tan J, Xu J: **Applications of electronic nose (e-nose) and electronic tongue (e-tongue) in food quality-related properties determination: A review.** *Artificial Intelligence in Agriculture* 2020, **4:**104-115.
26. Muller P, Salminen K, Nieminen V, Kontunen A, Karjalainen M, Isokoski P, Rantala J, Savia M, Valiaho J, Kallio P, Lekkala J, Surakka V: **Aroma classification by K nearest neighbors using ion-mobility spectrometry measurements**. *Expert systems with applications* 2019, **115,Jan**:593-606.
27. Men H, Jiao Y, Shi Y, Gong F, Chen Y, Fang H, Liu J: **Odor fingerprint analysis using feature mining method based on olfactory sensory evaluation.** *Sensors* 2018, **18**:3387.
28. Shi H, Zhang M, Adhikari B: **Advances of electronic nose and its application in fresh foods: A review.** *Critical reviews in food science and nutrition* 2018, **58:**2700-2710.
29. Nozaki Y, Nakmoto T: **Predictive modeling for odor character of a chemical using machine learning combined with natural language processing.** *PLoSONE* 2018, **13**: e0198475.

30. Shiba K, Tamura R, Sugiyama T, Kameyama Y, Koda K, Sakon E, Minami K, Ngo HT, Imamura G, Tsuda K, Yoshikawa G: **Functional nanoparticles-coated nanomechanical sensor arrays for machine learning-based quantitative odor analysis**. *Sensors* 2018*,* **3**:1592-1600.
31. Shiba K, Tamura R, Sugiyama T, Kameyama Y, Koda K, Sakon E, Minami K, Ngo HT, Imamura G, Tsuda K, Yoshikawa G: **Additive trees for the categorization of a large number of objects, with bootstrapping strategy for stability assessment: Application to the free sorting of wine odor terms.** *Food Quality and Preference* 2021 forthcoming*,* **89***.*
32. Murphy MC, Dweck CS: **Mindsets shape consumer behavior.** *Journal of Consumer Psychology* 2016*,* **26**:127-136.