Influence of Distal and Proximal Food Sensory Factors on Evaluations of Food Healthiness and Healthy Food Choices

Authors: Hu Guimei, Hu Guimei, Yan Yan, Yan Yan, Liang Xueying, Liang Xueying, Liu Wumei, Liu Wumei, Yan Yan, Yan Yan

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Abstract

Food sensory cues such as "color, aroma, and taste" are important factors influencing people's evaluation of food healthiness and healthy food choices; however, traditional classifications of sensory factors have failed to fully reflect the diversity of food sensory experiences in new technological environments. In this context, food sensory factors can be categorized into four types based on the detection distance of sensory organs (distal vs. proximal) and the source of experience (direct vs. indirect): proximal-direct sensory factors, proximal-indirect sensory factors, distal-direct sensory factors, and distal-indirect sensory factors. These four categories of sensory factors exert differential influences on food healthiness evaluation and healthy food choices through distinct psychological mechanisms. For distal senses, sensory factors from both direct and indirect experiences primarily operate through mental imagery simulation and cognitive processing mechanisms, whereas for proximal senses, sensory factors from direct experiences mainly influence through physiological arousal, brain reward, emotion, and memory, while sensory factors from indirect experiences still need to function via mental imagery simulation mechanisms. Meanwhile, sensory processing traits, sensory stimulus exposure context, and indirect experience context moderate the relationship between food sensory factors and psychological mechanisms, whereas food type and individual characteristics moderate the relationship between psychological mechanisms and food healthiness evaluation and healthy food choices. Finally, future research directions are proposed based on the above integrative framework.

Full Text

Preamble

The Impacts of Proximal and Distal Food Sensory Factors on Consumers' Food Healthiness Assessments and Healthy Food Choices

HU Guimei[1], YAN Yan[2], LIANG Xueying[1], LIU Wumei[2]
(1. School of Business Administration, Guangdong University of Finance, Guangzhou 510521, China;
2. School of Management, Lanzhou University, Lanzhou 730000, China)

Abstract: Sensory cues such as food "color, aroma, and taste" are important factors influencing people's assessments of food healthiness and their healthy food choices. However, traditional classifications of sensory factors fail to adequately capture the diversity of food sensory experiences in new technological environments. Against this backdrop, food sensory factors can be categorized into four types based on the detection distance of sensory organs (distal vs. proximal) and the source of experience (direct vs. indirect): proximal direct sensory factors, proximal indirect sensory factors, distal direct sensory factors, and distal indirect sensory factors. These four types of sensory factors exert differential influences on food healthiness assessments and healthy food choices through distinct psychological mechanisms. For distal senses, both direct and indirect sensory factors primarily operate through mental imagination, simulation, and cognitive processing mechanisms. For proximal senses, direct sensory factors mainly influence through physiological arousal, brain reward, emotion, and memory, while indirect sensory factors still rely on mental imagination and simulation mechanisms. Meanwhile, sensory processing traits, sensory stimulus exposure situations, and indirect experience contexts moderate the relationship between food sensory factors and psychological mechanisms, while food types and individual characteristics moderate the relationship between psychological mechanisms and food healthiness assessments and healthy food choices. Finally, future research directions are proposed based on this integrative framework.

Keywords: distal food sensory factors, proximal food sensory factors, direct experience, indirect experience

Consumers frequently face various food temptations. Foods that are "colorful, aromatic, and flavorful" often whet the appetite but can also lead people to overlook health considerations. Research shows that regular consumption of unhealthy foods negatively impacts insulin and blood sugar control [?, ?], while physical abnormalities such as obesity, coronary heart disease, and digestive disorders have been linked to high intake of energy-dense, high-fat, and high-salt foods [?, ?, ?]. This demonstrates that healthy eating is crucial for disease prevention, and understanding what factors influence food healthiness assessments and healthy food choices can nudge consumers toward healthier dietary behaviors. Previous studies have explored various factors affecting healthy eating, such as nutrition labels, health claims, packaging, food types, ingredients, origins, and other sensory characteristics [?, ?, ?, ?, ?]. Domestic scholars have also systematically investigated how embodied mental simulation [?, ?], emotions [?, ?], and food labels [?, ?] influence dietary consumption behaviors, as well as nudging interventions for healthy eating [?, ?, ?]. Building on these studies, this paper focuses on food sensory factors to review and evaluate existing research on consumer food healthiness assessments and healthy food choices.

Examining how food sensory factors influence consumer perceptions of food healthiness and healthy food selection behaviors is both necessary and important. At the practical level, all foods and their packaging contain multiple sensory cues related to color, aroma, and taste, which have direct and significant impacts on how consumers evaluate food healthiness and choose healthy foods. Compared to external cognitive cues like nutrition labels and health claims that require elaborate processing, food sensory cues tend to trigger more automatic psychological processing [?, ?], exerting a more direct and rapid influence on healthy eating judgments. With the proliferation of digital marketing environments, consumers can not only directly contact various food sensory cues in offline physical settings but also virtually experience them through digital media. Marketers often leverage these sensory cues for promotional purposes to encourage greater food consumption. However, it remains unclear whether and how food sensory factors in different experiential contexts facilitate or hinder consumer assessments of food healthiness and whether they similarly affect healthy food choices. Theoretically, the five sensory organs differ in their detection distances for stimuli—eyes and ears can perceive stimuli from great distances, while nose, tongue, and skin require much closer proximity. Scholars thus categorize the five senses into proximal senses (olfaction, touch, taste) and distal senses (vision, hearing) based on detection distance [?, ?, ?]. Recent research shows that online virtual influencers (e.g., virtual streamers) can provide satisfactory distal sensory experiences (visual, auditory) but struggle to meet proximal sensory needs (touch, smell, taste) [?, ?], demonstrating differential effects across sensory types. Yet whether proximal and distal food sensory factors differentially influence consumer assessments of food healthiness and healthy food choices remains underexplored theoretically. This paper aims to address these practical puzzles and theoretical gaps.

Based on prior research, this paper first classifies food sensory factors into proximal senses (olfaction/touch/taste) and distal senses (vision/hearing), while also distinguishing between direct experience (offline physical environments) and indirect experience (online/advertising/packaging). This yields four categories of food sensory factors. We then systematically review how different types of food sensory factors influence food healthiness assessments and healthy food choices, along with their underlying mechanisms and boundary conditions. This paper's contributions are threefold: (1) It deepens sensory marketing theory. Existing sensory research primarily classifies factors by physiological sensory organs, largely ignoring differences in stimulus detection distances and failing to capture the psychological commonalities between distal and proximal senses. Moreover, digital technologies have made virtual sensory experiences ubiquitous, yet current research lacks integrative consideration of sensory factors and experiential contexts. Our dual-dimensional classification based on sensory distance and experiential context provides a novel framework for sensory research. (2) It advances healthy food marketing research. While prior studies focus on how labels and health claims can promote healthy choices, food sensory factors—especially intrinsic food properties—more effectively trigger automatic psychological processing and imagination. Our focus on sensory factors can uncover underlying drivers of healthy dietary choices. (3) It enriches research on consumer experiences in new technological environments. As consumers constantly switch between real and virtual sensory experiences in digital marketing contexts, considering direct and indirect experiential contexts can help marketers better understand digital consumption psychology and create immersive virtual food sensory experiences.

2.1 Proximal and Distal Senses

Humans primarily rely on five physiological sensory organs—eyes, ears, skin, tongue, and nose—to perceive external stimuli, forming perceptual judgments that influence attitudes and behaviors [?, ?]. Research shows that these five sensory organs differ in their detection distances for stimuli [?, ?]. For instance, people can see sound or light waves miles away, but tactile, olfactory, and gustatory stimuli must be experienced at relatively close range. Compared to vision and hearing, touch, smell, and taste produce more salient and acute bodily sensations—for example, people easily detect the pungent smell of chili peppers or the slight prickliness of wool [?, ?, ?]. Classifications of proximal and distal senses vary slightly across research contexts. [?, ?] measured consumers' spatial distance perceptions of sensory imagery generated by the five senses, finding the order from nearest to farthest was taste, touch, smell, hearing, and vision. They selected taste and touch as proximal stimuli and hearing and vision as distal stimuli, while smell was excluded due to its moderate perceived distance. [?, ?] classified vision and hearing as distal senses and touch, smell, and taste as proximal senses. This paper categorizes smell as a proximal sense for three reasons: First, we follow the proximal-distal sensory descriptions used in most prior research [?, ?, ?, ?]. Second, food aromas typically require close proximity to be perceived. As [?, ?] note, olfactory signals are received by olfactory nerves in the nasal cavity from volatile molecules emanating from food, then processed in the brain's olfactory center—characteristics of proximal senses. Third, considering the directness versus indirectness of sensory experiences, smell remains difficult to realistically simulate in indirect digital virtual environments, unlike vision and hearing. Therefore, we classify smell, which requires nasal contact to detect odor stimuli, as a proximal sense.

Additionally, auditory cues related to food have unique characteristics. Foods themselves typically do not produce sound, but may generate sounds during preparation (e.g., the sizzling of steak) or when chewed in the mouth (e.g., the crunch of potato chips) [?, ?]. The former resembles ambient sounds that can be heard without direct bodily contact, while the latter can only be experienced inside the mouth. Thus, food-related auditory cues possess both distal and proximal sensory characteristics. Accordingly, this paper classifies different types of food sound cues into distal food auditory and proximal food auditory categories.

2.2 Direct and Indirect Sensory Experience

In current digital marketing environments, consumers encounter food sensory cues in increasingly diverse contexts, with many cues only accessible through digital environments (e.g., advertising images/videos, online purchasing platforms). Existing sensory marketing research has clearly distinguished between direct and indirect tactile experiences [**?**, **?**, **?**, **?**]. This paper argues that all five types of food sensory factors can be divided into direct and indirect sensory experiences based on whether they directly act on human senses: the former refers to direct contact scenarios where consumers physically see/hear/touch/smell/taste foods, while the latter refers to scenarios where consumers can only indirectly perceive food sensory cues through images/videos or by observing others' behaviors. Combining sensory organ detection distance with food sensory experience contexts, our classification of food sensory factors is shown in Table 1 .

Table 1: Classification of Food Sensory Factors

	Direct Sensory Experience	Indirect Sensory Experience
Distal Vision (color, shape, aesthetics, other visual cues)	External auditory (food preparation sounds, etc.)	Digital images (advertising/e-commerce)
Proximal Olfaction (bread, fruit aromas, etc.)	Touch (texture, temperature, weight, etc.)	Digital images (advertising/e-commerce)
Proximal Taste (salty, sweet, umami, etc.)	Internal auditory (food chewing sounds, etc.)	Language descriptions/broadcasting
		Watching others smell
		Digital images (advertising/e-commerce)
		Language descriptions/watching others taste

3.1.1 Distal Direct Sensory Factors Perspective

Food Visual Appearance. First, **food color.** Research finds that people habitually associate bright colors with health/nutritional value, while dull or less colorful foods may be perceived as less healthy or nutritious. For example, blue is considered a highly unappealing food color for meat and fish [?, ?], whereas salads with greater red-green color contrast are more popular than those with less contrast [?, ?]. This stems from consumers' explicit belief that "colorful = healthy," assuming more colorful foods contain higher proportions of vegetables and thus greater overall nutritional value [?, ?]. Second, **food shape/form.** Round (vs. angular) shapes are more strongly associated with unhealthy/indulgent food preferences [?, ?], while symmetrical (vs. asymmetrical) shapes are more strongly linked to healthy food preferences [?, ?, ?]. Anthropomorphizing food shapes can imbue foods with perceived pain sensitivity, generating negative emotions [?, ?]. However, anthropomorphizing meat dishes actually encourages consumers to choose healthier meat options over less healthy but tasty alternatives, as the health benefits of eating meat provide a strong justification that eliminates guilt about animal suffering [?, ?]. Additionally, food visual form influences healthiness assessments—greater physical transformation (e.g., apples processed into juice or sauce) implies higher mechanical processing and thus greater perceived unhealthiness and calorie content [?, ?]. Third, **food visual aesthetics.** Consumers hold a fundamental belief that "pretty = healthy," leading them to misjudge the healthiness of less attractive foods and make unhealthy choices [?, ?]. However, when food is extremely beautiful, consumers may reduce consumption out of reluctance to destroy its aesthetic appeal [?, ?]. The effect of aesthetics on healthy eating is inconsistent—some studies find that unattractive produce does not affect healthiness evaluations [?, ?]. Fourth, **other visual cues.** Food portion size influences healthiness judgments—consumers tend to perceive a large portion of potato chips as containing more calories and being less healthy than three small portions of equal total quantity [?, ?]. For foods already perceived as healthy, however, larger portions produce the opposite indulgence effect—consumers estimate fewer calories in larger (vs. smaller) portions of healthy foods like almonds and thus prefer larger portions, even though they contain more calories [?, ?]. Food presentation position also affects healthiness assessments—displaying healthy foods to the left (vs. right) of unhealthy foods enhances preference for and consumption of healthy foods, as people subconsciously associate "healthy on the left, unhealthy on the right," and matching food positions to this association improves processing fluency [?, ?].

Food Preparation Sounds and Name Pronunciation. The grinding sound of coffee beans, the sizzling of steak served tableside—these food preparation sounds subtly influence consumer evaluations [?, ?, ?]. When preparation sounds align with food evaluations, they enhance assessments of taste and aroma pleasantness [?, ?]. For example, hearing bacon sizzling in a pan leads participants to perceive more bacon in the food; hearing a hen clucking suggests more eggs [?, ?]. Food name pronunciation also affects healthiness assessments—brand names containing lower-frequency sounds (e.g., b, d, g, o, u) are more likely to be perceived as unhealthy [?, ?], while names that sound unhealthy reduce perceived healthiness [?, ?].

3.1.2 Distal Indirect Sensory Factors Perspective

Food Packaging Visual Appearance. First, **packaging color.** Food packaging color serves as a signal for healthiness judgments. Cool colors like blue-green are typically associated with health, while warm colors like red symbolize unhealthiness [?, ?]. Red (vs. blue) yogurt packaging, despite conveying richer taste and sweeter flavor, is perceived as less healthy [?, ?]. Consumers more readily associate vivid, saturated colors, dark glass packaging, and artificial-looking colors (e.g., heather/celadon) with indulgent, unhealthy foods \cite{Cavallo & Piqueras-Fiszman., 2017; Mead & Richerson, 2018}. Second, **packaging shape.** Round packaging is perceived as less healthy than angular packaging because round shapes evoke sweetness associations (e.g., butter cookies in round packaging are judged tastier) [?, ?]. Slender (vs. non-slender) packaging shapes make foods appear healthier—tall, thin packages lead consumers to perceive lower calorie content than short, wide packages [?, ?]. Cute packaging increases perceived tastiness but decreases perceived healthiness [?, ?]. Third, **other packaging visual cues.** Placing food images at the bottom (vs. top) of packaging increases expected and actual taste perception, helping consumers make healthier dietary decisions [?, ?]. Chocolate packaged in healthy materials (cardboard) is perceived as healthier than identical chocolate in unhealthy materials (plastic) [?, ?].

Digital Food Visual Appearance. Various food image features in digital media environments also influence food cravings and healthiness assessments. Compared to real chocolate, digitally generated virtual chocolate images elicit similar appetite and arousal responses at both psychological and physiological levels [?, ?]. Low-realism images (e.g., hand-drawn illustrations, rotating animations) lead participants to consume more potato chips, as these chips appear healthier in unrealistic images [?, ?]. Presenting food images from a bystander perspective (vs. diner perspective) reduces visual vividness, making foods appear less appealing and decreasing desire for unhealthy foods [?, ?]. Static (vs. dynamic) food images reduce perceived freshness and thus perceived healthiness [?, ?]. Messy (vs. tidy) food presentation, such as scattered crumbs, increases likelihood of choosing unhealthy foods [?, ?].

Food Packaging Sounds. [?, ?] cleanly manipulated packaging sound effects by playing audio stimuli through headphones (avoiding tactile interference), finding that hearing a bag's "rustling sound" (vs. white noise) significantly increased crispiness ratings for potato chips. Another study found that increasing the popping sound rate in glass (vs. plastic) bottles led participants to perceive higher carbonation levels in soda water; even simply increasing overall volume or enhancing high-frequency sounds raised carbonation assessments [?, ?].

3.2.1 Proximal Direct Sensory Factors Perspective

Food Tactile Properties. Food tactile characteristics primarily include texture (softness/hardness, smoothness), temperature, and weight, all of which influence healthiness assessments. First, **texture.** Consistent with theories of oral sensation, oral tactile sensations associated with soft (vs. hard) and smooth (vs. rough) foods lead to higher calorie estimates, as this "oral tactile–calorie estimation" effect is driven by reduced chewing effort and higher tactile perception of soft/smooth foods [?, ?]. Second, **temperature.** Consumers tend to perceive hot foods as containing more calories because cold (vs. hot) foods are less filling and less tasty [?, ?]. Third, **weight.** Heavier foods are perceived as containing more fat, sugar, and salt, while lighter foods are seen as healthier but less filling [?, ?, ?].

Food Odor. Food-related odors enhance preference for congruent foods. For example, environments filled with sweet bread aroma reduce selection of high-fiber dark bread [?, ?], while fruit scent (vs. no scent) increases fruit choice over chocolate cake for afternoon snacks [?, ?]. Eye-tracking attention experiments show that exposure to healthy scents (e.g., fruit) makes participants more likely to fixate on and select healthy foods compared to unhealthy scents (e.g., sausage) [?, ?]. However, [?, ?] found that prolonged exposure (over two minutes) to indulgent food ambient scents (e.g., cookie aroma) reduced unhealthy food purchases, suggesting that extended exposure to indulgent scents satisfies brain reward circuits, reducing actual desire for indulgent foods.

Food Taste. Taste is a crucial cue for healthiness perception. People widely hold the belief that "unhealthy = tasty," assuming unhealthy foods are more delicious while healthy foods taste worse [?, ?]. High-sweetness foods lead to greater consumption and increased preference for other sweet foods and beverages [?, ?]. Salty foods reduce perceived healthiness and increase calorie estimates compared to regular-flavor foods [?, ?]. Fried foods, despite their appealing crispy texture, are perceived as high in calories and fat and thus unhealthy [?, ?].

Food Chewing Sounds. Many foods produce distinctive sounds when chewed or swallowed, such as the crunch of cookies or chips. These auditory cues influence healthiness judgments. For identical potato chips, amplifying chewing sound volume or high-frequency components through headphones makes them seem fresher and crispier; reducing sound intensity and high-frequency components makes them seem softer and less fresh [?, ?]. Even soft foods are perceived as rougher, crunchier, and more satisfying under electromyography chewing sound conditions [?, ?]. When heard food sounds match the evaluated food type, evaluations are more pleasant—hearing potato chip crunching (vs. cola drinking) improves taste ratings for chips [?, ?].

3.2.2 Proximal Indirect Sensory Factors Perspective

Food Packaging/Container Tactile Properties. Smooth (vs. matte) packaging leads consumers to expect higher fat and sugar content [?, ?], while matte packaging makes artificial foods (e.g., ketchup, soda) seem more natural and tasty [?, ?]. Container tactile properties also affect healthiness judgments.

Vanilla ice cream sampled from smooth (vs. sharp) cups is judged sweeter, while uneven, rough containers enhance salty perception of potato chips compared to smooth surfaces [?, ?]. Beverages from sturdy (vs. flimsy) cups are perceived as better tasting and higher quality [?, ?]. Similarly, yogurt tasted from heavier (vs. lighter) plates receives higher texture ratings [?, ?].

Imagined/Digitally Simulated Food Tactile Properties. Since proximal sensory experiences are difficult to fully realize in advertising images or virtual digital environments, marketers often provide alternative sensory cues to substitute for actual touch. [?, ?] used images of hands touching products to evoke vicarious touch sensations, increasing positive attitudes toward online beverage and coffee videos. [?, ?] showed that direct touchscreen ordering (e.g., iPad) leads to more hedonic, unhealthy choices (e.g., chocolate cake), while indirect ordering (e.g., mouse) leads to more rational, healthy choices (e.g., fruit salad). When food presentation cues align with tactile action simulation, they make resisting food temptation more difficult—for example, placing cutlery to the right (vs. left) of cake in ads facilitates mental imagery of eating the cake, increasing appeal [?, ?].

Imagined/Digitally Simulated Food Odor. Olfactory cues can also be simulated through mental imagination. Imagined strawberry odor affects sucrose sweetness estimates similarly to actual strawberry odor [?, ?], suggesting imagined odors share characteristics with perceived odors. [?, ?] demonstrated that for foods in print ads, asking participants to imagine smelling the food (vs. control) enhanced physiological (salivation), evaluative, and consumption responses.

Imagined/Digitally Simulated Food Taste. Taste experiences can also be perceived indirectly through language descriptions, mental imagery, or digital media. Verbal ads emphasizing taste alone (vs. multi-sensory descriptions) improve taste perception and appeal of healthy foods [?, ?]. The "Meta Cookie+" system uses specialized equipment to create seemingly real cookie tasting experiences—an augmented reality "simulated taste" method [?, ?]. It remains unclear whether this "taste illusion" differentially affects healthy versus unhealthy foods.

Imagined/Digitally Simulated Food Chewing Sounds. When actual chewing sounds cannot be experienced, consumers can indirectly experience them through media playback or mental imagination. Participants who listened to potato chip chewing or coffee drinking sounds through headphones rated congruent food odors as more pleasant—hearing chip chewing (vs. coffee drinking) significantly improved pleasantness ratings for chip aroma [?, ?].

3.3 Interactive Effects of Proximal and Distal Senses on Food Healthiness Assessment and Healthy Food Choices

"Complete in color, aroma, and taste" represents comprehensive food evaluation. Food-related sensory cues not only function independently but also interactively influence healthy eating attitudes.

First, taste perception depends not only on gustatory stimuli but also on integration of multiple sensory inputs, which converge in the orbitofrontal cortex region known as the "higher-order taste cortex" [?, ?]. Different visual features (color, shape, texture) have strong cross-modal associations with taste [?, ?]. For example, red noodles are associated with spiciness, yellow noodles with saltiness [?, ?], and darker-colored cherry drinks are perceived as stronger in flavor [?, ?].

Second, olfactory and gustatory information show cross-modal associations. Strawberry (vs. peanut butter) odor enhances sweet perception but not salty perception [?, ?]. Some scholars argue that odor-induced taste enhancement reflects integrated cross-modal activity representing discrete functional sensory perception [?, ?].

Third, tactile information affects taste perception. Food surface roughness significantly influences taste—rough surfaces are rated as more sour [?, ?], while smooth textures are perceived as sweeter [?, ?]. Holding a stale pretzel makes a fresh pretzel in the mouth seem less fresh and crisp, showing that hand tactile information alone can alter freshness and crispness perceptions [?, ?].

Furthermore, different auditory features influence taste perception. Participants eating potato chips rate them as "fresher" and "crispier" when hearing louder or high-frequency amplified sounds [?, ?]. Ice cream named "Frosh" is perceived as creamier and smoother than "Frish" because the "o" sound better matches smooth, rich, and full-bodied textures [?, ?].

Overall, multiple sensory cues create stronger appetite stimulation than single cues, making resisting unhealthy foods more difficult [?, ?], as multi-sensory cues enhance mental simulation intensity and increase craving satisfaction. Unhealthy food images more easily trigger pleasurable taste responses [?, ?], possibly because they elicit greater attention and increased activity in reward-related brain regions (orbitofrontal and insular cortices) compared to healthy food images [?, ?]. In advertising contexts where consumers can only access limited sensory cues, they rely on cross-modal interactions to create multimodal mental imagery of missing cues. Visual stimuli congruent with olfactory cues in ads activate olfactory imagery, enhancing taste perception and appetite [?, ?].

Finally, vicarious proximal sensory experiences from images or virtual digital environments can interact with real sensory experiences. Contact with chocolate images followed by chocolate odor exposure enhances visual stimulus attractiveness and increases subjective craving and brain reward responses [?, ?]. Virtual food tactile and olfactory sensations can simulate real experiences—compared to viewing virtual food alone, simultaneously simulating touch and smell increases satiety [?, ?]. Theoretically, immersive virtual digital environments may create sensory experiences similar to actual food consumption, thereby reducing actual food intake [?, ?].

4 Psychological Mechanisms Driving the Effects of Food Sensory Factors on Healthiness Assessments and Healthy Food Choices

What are the differential mechanisms through which different types of food sensory factors influence consumer healthiness assessments and healthy food choices? Do different sensory factors operate through the same mechanisms? First, proximal and distal sensory factors affect healthiness assessments and choices through different mechanisms. Proximal sensory experiences require contact with bodily receptors (nasal cavity, mouth, skin) and thus exert more direct effects, primarily through neuropsychological mechanisms. Research confirms that ambient odors detected by the nose play important roles during eating: detecting food sources, inducing appetite, and influencing food preferences, selection, and intake [?, ?]. For example, smelling roasted sweet potato aroma triggers appetite through physiological arousal mechanisms. Distal sensory stimuli can be detected from afar without bodily contact, producing lower physiological arousal and requiring consumers to activate perception and behavioral decisions through mental simulation and cognitive processing. Second, direct versus indirect experiences show greater differential effects for proximal than distal senses. Digital technology has made visual and auditory cues in digital materials nearly equivalent to real experiences, with minimal differences between direct and indirect audiovisual experiences. For instance, digitally generated virtual food images elicit similar appetite and arousal responses as real foods [?, ?], and [?, ?] confirm that virtual digital environments can adequately satisfy distal sensory experiences. However, for proximal senses like smell, touch, and taste, direct experiences are vivid and immediate, primarily influencing healthiness evaluations and food choices through physiological arousal, emotion, and memory. When consumers can only access vicarious indirect experiences through audiovisual, action, or language cues, physiological arousal is relatively low, and effects depend mainly on sensory imagery and mental simulation. Based on this analysis, we discuss the mechanisms for distal and proximal sensory factors separately.

4.1 Mechanisms of Distal Sensory Factors' Effects on Food Healthiness Assessment and Healthy Food Choices

Distal senses dominated by vision and hearing cannot directly reach internal bodily receptors like proximal senses. Therefore, their influence on food healthiness assessments and healthy food choices operates primarily through mental simulation and cognitive processing mechanisms. Since direct and indirect experiences of distal audiovisual sensory factors differ little, both affect consumer healthiness assessments and choices through the following mechanisms.

4.1.1 Mental Imagination and Simulation Mechanisms Mental simulation is defined as "the mental re-enactment of perceptual, motor, and introspective states acquired through experience interacting with the world, body, and mind," representing the reproduction of past sensory experiences [?, ?]. Various sensory stimuli form mental images in individuals' minds—sensory imagery that constitutes an important component of mental simulation [?, ?]. For example, when tasting chocolate, the brain automatically records various sensory experiences (aroma, shape, color, texture, melting sensation on the tongue). Encountering chocolate later (through objects, images, or descriptions) triggers mental simulation of previous sensory experiences, activating brain regions involved in the original tasting [?, ?], thereby influencing subsequent consumer responses [?, ?]. Mental simulation enhances action readiness and affordance, preparing people for actual behavioral responses [?, ?], such as salivating in preparation for food intake after mentally simulating food [?, ?]. The Chinese idiom "quenching thirst by thinking of plums" vividly illustrates such physiological responses from mental simulation. Neuroscience research shows mental simulation activates brain cortical regions related to taste, smell, and auditory stimuli [?, ?, ?], so mentally imagining a food's sensory experience can increase direct craving [?, ?]. Prior research demonstrates mental simulation influences behavior and attitudes by stimulating positive emotional responses [?, ?]. The richer the sensory cues presented, the clearer the mental imagery and the higher its quality, resulting in stronger food cravings [?, ?, ?]. [?, ?] further distinguish two types of mental imagery: deliberate and automatic, existing on a continuum. Deliberate imagery is a top-down, intentional process under explicit instruction, while automatic imagery occurs more naturally and spontaneously when seeing objects or pictures. Both direct and indirect visual and auditory food sensory cues can simultaneously trigger these two types of sensory mental imagery, jointly influencing mental simulation content.

Food-related mental simulation typically involves three aspects: First, **action mental simulation** of eating behaviors. For example, [?, ?] found that when ad visuals facilitate mental simulation of eating actions (e.g., a pizza with a missing slice), purchase intentions increase. Dynamic cues (e.g., jumping fish) make foods seem fresher than static images (e.g., still fish) [?, ?]. Second, **sensory experience mental simulation** directly targeting sensory experiences—imagining the food's smell, texture, appearance, and deliciousness. Numerous studies confirm that mental simulation of food sensory cues enhances attractiveness [?, ?, ?]. Third, **process vs. outcome simulation** of eating. Compared to control conditions, process simulation (imagining eating) increases unhealthy food choices, while outcome simulation (imagining post-eating results) promotes healthier choices [?, ?].

4.1.2 Cognitive Processing Mechanisms The cognitive mechanisms through which food sensory factors influence healthiness assessments and healthy choices include conceptual metaphor and heuristic information processing. When food sensory cues align with existing metaphors or heuristic beliefs, processing fluency increases, facilitating more positive healthiness evaluations and healthy food choices.

First, **conceptual metaphor** drives effects by systematically mapping from concrete to abstract conceptual domains—using simple concepts (e.g., temperature) to express complex ones (e.g., psychological feelings), reflecting important cognitive features [?, ?]. These metaphors intuitively influence daily decisions, including food selection and consumption [?, ?]. For example, consumers hold spatial metaphors like "healthy left, unhealthy right" [?, ?], "light = healthy" [?, ?, ?], and "slender = healthy" [?, ?], using these to judge food healthiness.

Second, **heuristic information processing** involves using limited knowledge to simplify decision rules and make rapid judgments [?, ?]. For instance, the widespread belief that "unhealthy = tasty" and "healthy = not tasty" leads people to find unhealthy foods like ice cream and chocolate cake irresistible despite high sugar and calorie content [?, ?, ?]. Additionally, because healthier foods often cost more, consumers develop a "healthy = expensive" heuristic [?, ?]. They also believe unhealthy foods are more filling than healthy foods ("healthy = less filling"), requiring larger quantities of healthy foods for equivalent satiety [?, ?].

4.2 Mechanisms of Proximal Sensory Factors' Effects on Food Healthiness Assessment and Healthy Food Choices

Proximal sensory factors affect individuals more directly. When proximal sensory cues are directly experienced, they primarily influence healthiness evaluations and eating desires through physiological arousal triggering brain reward mechanisms and emotional responses. However, indirectly experienced proximal sensory cues still operate through mental imagery and simulation mechanisms.

4.2.1 Physiological Arousal and Brain Reward Proximal sensory experiences involve more internal bodily sensations than distal senses, producing more direct and intense physiological arousal. First, tactile information awakens the physiological nervous system to identify stimulus types. Direct hand contact with food significantly enhances food attractiveness and makes resisting temptation more difficult compared to indirect contact using toothpicks [?, ?]. [?, ?] identify two tactile mechanisms affecting food evaluation: discriminative input from hairless skin (e.g., fingers) and affective input from hairy skin (e.g., back of hand). Since food tactile contact primarily occurs through hands, direct food tactile information influences evaluation mainly through physiological neural arousal and discrimination. Second, olfaction is one of the most primitive sensory mechanisms, closely linked to breathing and instinctive alertness [?, ?, ?]. Olfactory cells react immediately and instinctively to odors [?, ?], with processing sometimes occurring before conscious awareness [?, ?]. [?, ?] propose that olfactory arousal follows an inverted U-shaped principle. Finally, taste bud reactions directly activate brain reward regions, affecting appetite and consumption. High-fat, high-sugar foods (e.g., desserts, fried foods) stimulate brain reward circuits, releasing dopamine and producing pleasure [?, ?]. This reward feedback mechanism creates cravings for high-fat, high-sugar foods, leading people to prefer these less healthy options [?, ?].

4.2.2 Emotion and Memory Proximal sensory experiences have more profound and lasting effects on emotion and memory than distal senses. Tactile sensations capture properties related to temperature, smoothness, and hardness, which 调动 emotions and influence behavior. [?, ?] found that holding hot (vs. cold) water made participants rate strangers as more "warm" and use more warmth-related words, as warm touch promotes social closeness and promotion focus [?, ?]. Direct (vs. indirect) food contact also increases psychological pleasure and food liking [?, ?]. Olfactory neural research shows smell has direct physiological connections to memory—[?, ?] notes that "olfaction connects directly to memory unlike other senses." Smell is also closely tied to emotion, with [?, ?] reporting that 75% of human emotions are triggered by odors, and pleasant ambient scents can stimulate positive emotions and purchase intentions. Beach scents alleviate discomfort from crowding, while fireplace scents enhance psychological comfort in sparsely populated stores [?, ?]. Different odors affect emotions differently: citrus and mint are pleasant, lavender and ginger neutral, while sulfurous chemical odors are unpleasant and even disgusting [?, ?]. Gustatory experiences also affect emotional judgments—participants drinking bitter beverages show more disgust than those drinking sweet or plain beverages [?, ?]. These tactile, olfactory, and gustatory stimuli generate emotions that produce approach or avoidance attitudes toward foods.

4.2.3 Mental Imagination and Simulation Mechanisms When proximal sensory cues cannot be directly perceived, people achieve vicarious sensory satisfaction through mental simulation. Tactile, olfactory, and gustatory cues can generate sensory mental imagery. Imagining food odors and textures creates mental imagery similar to real sensory experiences, enhancing food attractiveness [?, ?, ?]. However, when participants imagine multiple proximal sensory experiences simultaneously (e.g., taste, smell, and texture of dessert), they choose smaller portions than control participants [?, ?], suggesting that imagining multiple proximal sensory experiences produces vicarious satiety that reduces consumption. Unlike audiovisual mental imagery that can function independently, proximal sensory mental imagery often depends on visual imagery. [?, ?] found that olfactory imagery directly affects food consumption desire—imagining chocolate cake aroma increased salivation, but only when food images were simultaneously present. Thus, olfactory imagery's effects on food consumption, including anticipatory responses like salivation, depend on visual imagery or seeing the food [?, ?]. Following [?, ?], we propose that in direct experience contexts with multiple food sensory cues present, spontaneous mental imagery for proximal senses is generated; in indirect contexts without direct contact, proximal senses require cognitive instruction to generate mental imagery, primarily through deliberate mental imagery. Additionally, whether indirect proximal sensory experiences can trigger mental simulation depends on accompanying visual imagery—without it, proximal sensory mental simulation effects are substantially weakened.

5 Boundary Conditions for the Effects of Food Sensory Factors on Healthiness Assessments and Healthy Food Choices

In summary, proximal and distal food sensory factors influence food healthiness assessments and healthy food choices through mental simulation, cognitive processing, and physiological arousal mechanisms. Various factors moderate these effects, which can be categorized based on where they operate: (1) **Front-end moderators** between sensory factors and psychological mechanisms that affect mechanism activation or imagery generation, including sensory processing traits, sensory stimulus exposure situations, and indirect experience contexts; and (2) **Back-end moderators** between psychological mechanisms and healthiness assessments/choices that may not be directly related to mechanisms but affect final outcomes, including food characteristics and individual traits.

5.1.1 Sensory Processing Traits

Mental Imagery Generation Ability. Sensory mental imagery and simulation play crucial roles in both proximal and distal sensory factors, but their effectiveness depends on individuals' ability to generate vivid mental imagery [?, ?]. Some individuals habitually generate visual images when processing information, while others do not—this is a well-documented individual processing trait [?, ?]. The QMI (Betts' Questionnaire Upon Mental Imagery) systematically assesses individual differences in vividness of mental imagery across visual, auditory, tactile, gustatory, and olfactory modalities [?, ?]. Individuals with high imagery generation ability more easily form sensory imagery, especially in indirect contexts, and more readily experience spontaneous mental simulation, making them more susceptible to sensory stimuli [?, ?]. In food contexts, high-imagery individuals are more easily triggered by 色香味 cues to experience food cravings, and mental imagery/simulation mechanisms are more effective for them.

Cognitive Load. Cognitive load refers to the information processing burden during tasks. Generating sensory mental imagery consumes cognitive resources, so cognitive load limits imagery generation ability [?, ?]. [?, ?] found that high (vs. low) cognitive load significantly reduced hedonic value perception of appetizing food images. Concurrent sensory tasks also limit cognitive resources, impairing specific sensory abilities—visual tasks reduce visual image memory, while competing auditory tasks weaken auditory image recall [?, ?]. Tasks occupying visuospatial attention or working memory resources reduce self-reported cigarette cravings [?, ?]. In high cognitive load environments, touching food's effects on evaluation and consumption intentions weaken or disappear [?, ?].

Sensory Sensitivity. Sensory sensitivity refers to inherent individual differences in detecting and responding to sensory information [?, ?]. Children with higher tactile/gustatory/olfactory sensitivity eat fewer fruits and vegetables and are less willing to try new foods because their lower detection thresholds make them more sensitive to subtle sensory variations that affect produce [?, ?]. Individual differences in olfactory sensitivity exist [?, ?]. Highly sensitive individuals cannot ignore odors, and this sensitivity extends to olfactory imagery, often producing negative effects. While olfactory imagery instructions increase ad favorability for normal participants, they decrease favorability for those with high olfactory sensitivity [?, ?].

Need for Touch. Individual differences in need for touch affect responses to tactile cues. While 360-degree virtual stores enhance virtual shopping intentions through immersive sensory experiences, they have no effect on high need-for-touch consumers who prioritize direct tactile experience [?, ?]. In food contexts, high need-for-touch consumers are more sensitive to tactile cues—willing to pay more for tea in ceramic (vs. paper) cups, while low need-for-touch consumers' willingness to pay is unaffected by container material [?, ?]. Low need-for-touch individuals are more influenced by irrelevant, non-diagnostic cues, such as negative quality evaluations of mineral water when touching flimsy disposable cups [?, ?].

5.1.2 Sensory Stimulus Exposure Situations

Sensory Stimulus Exposure Duration. Exposure time length affects food responses. Prolonged exposure (over 3 minutes) to indulgent food ambient scents satisfies brain reward circuits' need for delicious, unhealthy food odors, reducing desire for unhealthy foods [?, ?]. Even imagined sensory experiences affect actual intake—participants who repeatedly imagined tasting a food subsequently consumed significantly less of that specific food but not other foods, demonstrating stimulus-specific habituation from mental representation [?, ?].

Conscious vs. Unconscious Exposure. Odor perception may be unconscious (unnoticed) or conscious (identified and recognized) [?, ?]. Pear scent exposure increases selection of low-energy fruit desserts [?, ?], while chocolate scent increases high-energy non-fruit dessert choices [?, ?]. However, these effects are inconsistent—bread and cucumber scents don't increase lunch selections of those foods [?, ?], and citrus scent doesn't affect supermarket fruit sales [?, ?]. This relates to conscious odor perception state—unconscious odor exposure likely triggers more behavioral responses than conscious exposure. When odors are identified consciously, subsequent cognitive processing is no longer implicit or automatic and may involve counteracting behavioral effects [?, ?]. Food odors appear to require unconscious perception to significantly influence food choices [?, ?, ?].

Sensory Stimulus-Food Characteristic Congruence. Exposure to odors, sounds, and other sensory cues increases appetite for foods with similar/congruent characteristics while decreasing appetite for incongruent foods [?, ?]. Brief exposure to pizza visual and olfactory cues increases expected intake of similar savory foods while decreasing sweet food intake

[?, ?]. High-calorie odor exposure increases appetite for high-calorie foods while decreasing low-calorie food desire, and vice versa [?, ?]. Similarly, hearing potato chip crunching (vs. coffee drinking) makes chip aroma more pleasant, while hearing coffee drinking (vs. chip crunching) makes coffee aroma more pleasant [?, ?].

5.1.3 Indirect Experience Contexts

Digital Technology. Virtual reality (VR), augmented reality (AR), digital interactive technology, and social media not only simulate real-world food experiences but also affect food perception and behavioral responses, as food perception is influenced by visual presentation [?, ?, ?]. AR technology that alters food visual size affects intake—smaller (vs. larger) visual cookie presentation reduces satiety ratings, leading to greater consumption [?, ?]. AR food stimuli are perceived as equally tasty as real foods, eliciting similar physiological arousal and making high-calorie (vs. low-calorie) foods seem tastier [?, ?]. AR visual food details enhance consumers' ability to mentally simulate eating, increasing likelihood of choosing indulgent unhealthy foods [?, ?]. Additionally, most adolescents prefer sharing high-calorie pastry and ice cream images over healthy fruit and vegetable images on social media [?, ?], demonstrating that digital technology enhances activation and mental simulation intensity of distal sensory cues, making resisting unhealthy foods more difficult.

Visual Perspective. Perspective angle moderates food healthiness assessments. First-person (vs. third-person) viewing of unhealthy food images increases brain activity in appetite (amygdala) and consumption (superior parietal gyrus) regions [?, ?]. First-person perspective mental simulation is easier and more emotionally stimulating, triggering affective projection of eating experiences. Third-person imagery provides fewer sensory components, weakens imagined eating sensations, and reduces emotional involvement, leading to more deliberate decision-making and reduced preference for unhealthy foods [?, ?, ?]. However, when goal centrality is low, third-person perspective hinders goal-congruent intentions and healthy behaviors—third-person viewers who perceive healthy eating as self-relevant choose sugary unhealthy foods [?, ?].

5.2.1 Food Types

Functional vs. Hedonic Foods. Functional foods provide specific nutritional benefits and help reduce disease risk or improve bodily functions (e.g., vitamin/mineral/fiber-rich foods), while hedonic foods emphasize taste satisfaction, often containing high sugar, fat, and salt [?, ?]. Sensory cues differentially affect these food types. Brighter colors increase consumption of hedonic but not functional foods [?, ?]. Round shapes increase preference for hedonic but not functional foods [?, ?]. Blue (vs. red) packaging makes functional foods seem healthier, while packaging color doesn't affect hedonic food healthiness evaluations [?, ?].

Healthy vs. Unhealthy Foods. Pre-existing healthiness judgments moderate sensory cue effects. Symmetrical shapes increase perceived naturalness and healthiness, but this effect disappears for highly unhealthy foods [?, ?, ?]. Light packaging enhances positive health effects for healthy foods but weakens them for unhealthy foods [?, ?]. Cute packaging reduces perceived healthiness of unhealthy foods but not healthy foods [?, ?]. Placing unhealthy food images at packaging bottom increases perceived flavor heaviness, but position doesn't affect healthy foods [?, ?]. For naturally perceived foods (e.g., tea), packaging surface material has no effect, but for artificially perceived foods (e.g., soda), matte packaging enhances naturalness perception [?, ?].

Salty vs. Sweet Foods. This distinction also moderates sensory effects. High-frequency (vs. low-frequency) sounds are perceived as healthier, but this effect only holds for salty foods, not sweet foods [?, ?]. Texture design enhances salty perception for regular potato chips but not for unsalted chips [?, ?].

5.2.2 Individual Characteristics

Health Consciousness/Future Thinking. Health consciousness reflects consumers' concern for their health. Highly health-conscious consumers focus on long-term health goals and are less influenced by external stimuli [?, ?]. [?, ?] found that restrained eaters are more susceptible to heuristic associations (vivid packaging = unhealthy), but consumers with high nutrition knowledge weaken this relationship by maintaining consistency between perceptions and behaviors. Episodic future thinking (EFT)—the ability to project oneself into the future—helps anticipate consequences of current behaviors [?, ?]. EFT training effectively reduces impulsive behaviors like overeating, drinking, and smoking by decreasing immediate appetite satisfaction and increasing long-term health goal value [?, ?]. Overweight and obese women who vividly imagined the future consumed fewer calories in eating tasks [?, ?].

Self-Control. Self-control is the autonomous ability to regulate thoughts, emotions, and behaviors [?, ?]. Stronger self-control helps resist unhealthy food temptations. High self-control consumers experience satiety faster with unhealthy than healthy foods, while low self-control consumers show no such effect [?, ?]. However, the relationship isn't linear—strong self-control doesn't necessarily reduce unhealthy eating, depending on attitudes toward unhealthy foods [?, ?]. Linking healthy foods to social norms enables healthier choices even under low self-control [?, ?]. Self-control also depends on perceived temptation level—when obesogenic environmental "temptation" exceeds psychological control capacity, people unconsciously overconsume [?, ?]. The mere presence of healthy options can increase indulgent food choices, especially among high self-control individuals [?, ?].

Sensation Seeking. This stable personality trait influences various behaviors. High sensation seekers prefer stimulating, novel activities and show the strongest association with spicy food preference [?, ?]. They are more willing to try novel foods regardless of healthiness [?, ?]. Western youth with high sensation seeking focus on short-term benefits (taste, low cost, social acceptance) from unhealthy foods, considering these immediate gratifications more important than less obvious long-term health costs [?, ?].

In summary, this paper elaborates on the differential effects of four types of sensory factors on food healthiness assessments and healthy food choices, along with their underlying psychological mechanisms and boundary conditions. Figure 1 [Figure 1: see original paper] presents our overall framework.

Figure 1: Overall Framework of This Review

6.1 Examining Differential Effects and Mechanisms of Proximal and Distal Sensory Factors

Previous food sensory research has paid limited attention to detection distance differences among the five sensory organs [?, ?, ?]. First, applying proximal-distal classifications to food sensory marketing can advance refined research on different sensory factors. Future studies should continue exploring differential effects of food proximal and distal sensory factors across experiential contexts. Second, sensory imagery and mental imagination play important roles in both proximal and distal factors, with vivid imagery potentially creating overwhelming cravings. Proximal and distal senses differ in imagery generation—distal senses can generate vivid imagery independently, while proximal sensory imagery often requires multiple sensory factors, particularly visual support [?, ?]. Future research should deepen understanding of these mechanisms. Additionally, research identifies two pathways—automatic and deliberate mental imagery [?, ?]—and this paper proposes their potential roles in food sensory effects, warranting empirical testing.

6.2 Exploring Interaction Effects of Direct and Indirect Sensory Experience Types

Beyond proximal and distal cues, direct and indirect sensory experiences offer cross-expansion opportunities. While direct vs. indirect tactile effects have received attention [?, ?, ?], other sensory modalities lack such focus. For example, direct visual sensory factors like food color evoke "colorful = healthy" beliefs, as colorful foods imply more nutrients [?, ?, ?]. However, indirect visual factors like packaging color negatively affect healthiness perception—vivid, saturated packaging is associated with indulgent, unhealthy foods [?, ?, ?, ?]. This shows identical sensory factors produce differential effects by experience source. Future research should explore interactive effects when indirect packaging sensory factors align or conflict with direct food sensory factors.

6.3 Exploring How Digital Sensory Factors Can Nudge Healthier Choices

Current research focuses on using digital technology to create immersive virtual sensory experiences that amplify sensory cues and make resisting unhealthy foods harder [?, ?, ?, ?]. However, healthy eating is more important for consumer well-being. How to leverage emerging digital technologies to enhance self-control against sensory temptation and increase healthy food choice warrants attention. Future research should explore using VR/AR to simulate realistic proximal sensory properties (texture, temperature, weight, odor) that trigger spontaneous mental imagery similar to direct proximal contact. However, mental imagery type and richness may differentially affect healthiness assessments. While AR visual information increases mental simulation and unhealthy food choices [?, ?], and single-sensory ads are more persuasive for healthy foods than multi-sensory ads [?, ?], imagining multiple proximal sensory experiences can reduce actual consumption of unhealthy foods through vicarious satiety [?, ?]. This suggests that for healthy food choices, richer sensory imagery isn't always better—spontaneous or single deliberate imagery may increase cravings, while multiple deliberate sensory imagery may produce vicarious satiety that reduces desire. Future VR technologies should consider these differential imagery effects in design.

Additionally, research should explore using digital technology to promote healthy eating by strategically altering food sensory attributes to make healthy foods more attractive, optimizing simulated sensory attribute combinations (texture, aroma, taste) to make healthy foods appealing. For unhealthy foods, digital technology could provide healthiness reminders to promote more rational choices.

6.4 Helping Consumers Re-evaluate and Re-examine Food Sensory Signals

Consumers hold numerous conceptual metaphors and heuristic beliefs about food sensory factors like "unhealthy = tasty" [?, ?, ?], "healthy = expensive" [?, ?], and "healthy = less filling" [?, ?], which hinder healthy dietary decisions. Future research should explore how to change these implicit beliefs and associations, cultivate consumers' ability to identify and appreciate healthy foods' sensory attributes, and establish correct food healthiness evaluation cognitions to help consumers better understand food sensory signals and develop healthy eating habits.

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