RUNNING HEAD: FACTORS INFLUENCING THE EYE APPEAL OF FOOD

Factors influencing the visual deliciousness / eye-appeal of food

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19 ABSTRACT

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21 In recent years, a growing number of academic researchers, as well as many marketing and
22 design practitioners, have uncovered a variety of factors that would appear to enhance the
23 visual attractiveness, or deliciousness, of food images to the typical consumer. This review,
24 which contains both narrative and systematic elements, critically evaluates the literature
25 concerning the various factors influencing the eye appeal of food images, no matter whether
26 there is an edible food stimulus physically present in front of the viewer or not. We start by
27 summarizing the evidence concerning the human brain's ability to rapidly determine energy-
28 density in a visual scene and pay attention accordingly. Next, we focus on the importance of
29 embodied mental simulation when it comes to enhancing visual deliciousness. Thereafter, we
30 review the literature on the importance of visual aesthetic features in eye-appeal. The wide
31 range of visual attributes that help to enhance food attractiveness include symmetry, shape,
32 freshness, glossiness, dynamic-presentation, etc. The review concludes with sections on the
33 importance of background/ambient lighting/colour, and the tricks used by those who digitally
34 manipulate images. Taken together, therefore, many different factors ultimately influence the
35 visual deliciousness of food images.

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37 KEYWORDS: ENERGY-DENSITY; FLAVOUR EXPECTATIONS; PLATING
38 AESTHETICS; FOOD DELICIOUSNESS; FOOD PORN; GASTROPORN; MENTAL
39 IMAGERY

1. Introduction

According to the cognitive neuroscience research, whenever we see something potentially edible, even when it is only portrayed visually in an image (e.g., in an advert or on a digital screen), our brain immediately estimates the food's likely energy density, and thereafter automatically directs its (visual) attention to the most energy-dense element in the scene (e.g., Suzuki, Cross, & O'Doherty, 2017; Tang, Fellows, & Dagher, 2014; Toepel, Knebel, Hudry, Lecoutre, & Murray, 2009; see also Garcia-Burgos, Lao, Munsch, & Caldara, 2017; Lee, Chien, Lin, & Yeh, 2022; Motoki, Saito, Suzuki, & Sugiura, 2021; Sawada, Sato, Toichi, & Fushiki, 2017). The research also demonstrates that embodied mental simulation occurs frequently with the viewer's brain imagining/simulating the act of eating the seen food along with its sensory properties. Making it easier for the viewer's brain to engage in such embodied mental simulation turns out to be an effective means of enhancing the visual deliciousness of food (e.g., see Speed, Papies, & Majid, 2021).

According to the cognitive neuroscience research, the hungry brain craving its favourite food devotes an impressive amount of energy (an average increase in brain metabolism of 24% when compared to resting state activity when no food related cues were presented) to the processing of food-related visual stimuli (Wang, Volkow, Telang, Jayne, Ma, et al., 2004; see also Versace Frank, Stevens, Deweese, Guindani, & Schembre, 2018). In such cases, it turns out to be the anticipation, or expectation, of fulfilment that drives the craving response (see Piqueras-Fiszman & Spence, 2015, for a review; see also Small, Veldhuizen, Felsted, Mak, & McGlone, 2008). Salivation and gastric preparation may also be triggered in response to food cues in anticipation of eating (see Keesman, Aarts, Vermeent, Häfner, & Papies, 2016; Moore & Konrath, 2015; Spence, 2011; Wooley & Wooley, 1973). Appropriate food images in this case include such things as the sight of a lemon being sliced or eaten (Birnbaum, Steiner, Karmeli, & Ilsar, 1974; Christensen & Navazesh, 1984).

Consumer neuroscience research has also started to provide some intriguing evidence concerning the neural responses to visual marketing communications for various food products (Plassmann, Ramsøy, & Milosavljevic, 2012; Spence, Velasco, & Petit, 2019 for a review). For instance, it turns out that food commercials elicit a significantly larger neural response than their non-food counterparts in those parts of the brain (e.g., the bilateral cuneus) that are thought to modulate food craving (Yeung, 2021). Neural responses to food ads have also been shown to correlate with the sales of indulgent food at the point-of-sale (Kühn, Strelow, & Gallinat,

2016). What is more, and as we will see later, the latest visual-enabling technologies are now starting to offer the consumer the opportunity to interact with food virtually (Velasco, Obrist, Petit, & Spence, 2018). Relevant here, a visual attentional focus on energy-dense foods has been linked to weight gain (e.g., Meule & Platte, 2016; Yokum, Ng, & Stice, 2011). The effects of the latter at the neural level are also now beginning to be studied (Huang, Zhao, & Wan, 2021; Smit, Meijers, & van der Laan, 2021; Van der Laan, Papies, Ly, & Smeets, 2022). Importantly, this has been shown to stimulate the mental simulation of food experiences, and even to exert a positive influence over the customer's purchase intention (Petit, Javornik, & Velasco, in press; Petit, Velasco, & Spence, 2019).

Perhaps unsurprisingly, those tasked with the marketing of food are constantly on the look-out for new ways in which to present the foods that they happen to be promoting in an ever more appetising way (Spence, 2017a, b; Van der Laan, De Ridder, Viergever, & Smeets, 2012; Vukmirovic, 2015). This is especially interesting given the growing interest in food porn and gastroporn (McDonnel, 2016), and increased interest from marketers and advertisers in knowing how best to present their products visually. The rapid growth of digital presentation/manipulation of food in online content also makes this review particularly timely. The statistics on rise of Instagram are impressive (Holmberg, Chaplin, Hillman, & Berg, 2016; Ledbetter, 2015; https://www.speakrj.com/audit/report/food/instagram), with around 85% images on social media site Instagram involving food (Holmberg et al., 2016) and over 60% on Pinterest (Kinard, 2016). In fact, according to Whittle (2018, p. 14), "Food is a great feeder of Instagram – some 208 million posts have been tagged on the photosharing app with the "food" hashtag since it was founded in 2010.

1.1. Review outline

The primary aim of the present review is to highlight the wide range of attributes that may be deemed attractive by the typical consumer. This narrative historical review (see Baethge, Goldbeck-Wood, & Mertens, 2019; Furley & Goldschmied, 2021, on the evaluation of the strengths of narrative reviews), backed-up by a systematic search of the literature (Furley & Goldschmied, 2021), focuses primarily on the responses of normal weight consumers to food imagery/advertisements. Nevertheless, the reader who is interested in the individual differences angle to the responsiveness to visual food cues will find a growing number of excellent papers

on the topic that have been published over the last decade or so (e.g., see Boswell & Kober, 2016; Castellanos, Charboneau, Dietrich, Park, Bradley, Mogg, & Cowan, 2009; Lavis, 2017; Lizia, Hemamalini, & Ravichandran, 2022; McSorley, Morriss, & van Reekum, 2017; Nijs, & Franken, 2012; Nummenmaa, Hietanen, Calvo, & Hyönä, 2011; Werthmann, Jansen, & Roefs, 2015).

While it is becoming increasingly common in certain areas, especially the medical sciences, to advocate for systematic reviews, along the lines of PRISMA guidelines (see Moher, Shamseer, Clarke, Ghersi, Liberati, Petticrew, Shekelle, & Stewart, 2015), such an approach tends to work much better when there is a commonly-identified term, such as a drug or disease name. However, in the case of the present study, no such common identifier really exists, thus making such a systematic approach rather more challenging. As such, the present review is primarily narrative in nature, another well-recognized approach (Baethge et al., 2019; Furley & Goldschmied, 2021; Grant & Booth, 2009). That said, it is supported by PRISMA guidelines. In particular, literature databases (Web of Science, Scopus, ProQuest) were searched using a search term (‘visual deliciousness’ OR ‘gastroporn’ OR ‘food porn’). We focused on “articles” (not review, book, book chapter, or conference papers) that were written in English. The studies identified by the search terms are shown in **Appendix Table A**. The flowchart of the PRISMA systematic review is shown in **Figure 1**.

INSERT FIGURE 1 ABOUT HERE

2. Energy-density and visually-appealing foods

It has long been suggested that we eat first with our eyes (e.g., Apicius, 1936; Mühl & von Kopp, 2017; Petit, Javornik, Velasco, in press; Spence, Okajima, Cheok, Petit, & Michel, 2016). In fact, the human brain can estimate the energy density (e.g., Suzuki, Cross, & O’Doherty, 2017; Tang et al., 2014), and likely macronutrient content, of a food following an extremely-brief visual exposure (Motoki et al., 2021). Here, in passing, one might consider whether Crouzet, Joubert, Thorpe, and Fabre-Thorpe’s (2012) finding that animals are detected prior to scene categorization is more evolutionarily related to the detection of threat or food (see also New, Cosmides, & Tooby, 2007). Research by Wang et al. (2004) documented a huge (i.e., 24%) increase in whole brain activity in response to the sight (and smell) of their participants’ favourite foods when they were hungry (see also Sawada et al., 2019; Schur, Kleinhans,

Goldberg, Buchwald, Schwartz, & Maravilla, 2009; Tapper, Pothos, & Lawrence, 2010). When Wang et al.'s participants were eventually allowed to consume the food that they had been craving, their cerebral blood flow soon declined (see also Small et al., 2008). In this sense, craving can be considered as representing the anticipation – perhaps even the eager anticipation of food with the associated expectation of fulfilment (e.g., Fletcher, Pine, Woodbridge, & Nash, 2007; Kemps & Tiggeman, 2007, 2010, 2013; Moore & Konrath, 2015; Spence, 2012).

Humans exhibit a strong preference for the taste of those foods that are high in both sugar and fat (e.g., Abdallah, Chabert, Le Roux, & Louis-Sylvestre, 1998; DiFeliceantonio, Coppin, Rigoux, Thanarajah, Dagher, et al., 2018; Drewnowski & Greenwood, 1983; Gearhardt, Treat, Hollingworth, & Corbin, 2012). High sugar (carbohydrates) and fat foods tend to be valued more and potentiate the brain's reward circuits to a greater extent than those foods that happen to be high in either fat or sugar (DiFeliceantonio et al., 2018). The taste/flavour expectations that are generated prior to tasting a food are often crucial as far as controlling the viewer's subsequent food behaviour is concerned. In fact, according to research by Avery, Liu, Ingeholm, Gotts, and Martin (2021), the human brain may well compute the different taste properties that are likely to be associated with any food that happens to be displayed, and what we consume exerts an influence over the brain's subsequent response to visual food cues. For example, the ingestion of fructose, as compared to glucose, results in a significantly larger neural response to food cues in both the visual cortex and the left orbital frontal cortex (Luo, Monterosso, Sarpelleh, & Page, 2015).

2.1. Energy density and visual attentional capture

The energy-density of the displayed food turns out to be an important factor in terms of determining the spatial focus of the consumer's visual attention (e.g., Harrar, Toepel, Murray, & Spence, 2011; Toepel et al., 2009; and see Motoki, Satio, & Onuma, 2021, for a review). The biasing of a consumer's visual attention toward energy-dense food stimuli appears to vary as a function of an individual's weight status/concerns, and also to be more pronounced in those people who happen to be hungry (e.g., Sawada, Sato, Minemoto, & Fushiki, 2019; van der Laan, De Ridder, Viergever, & Smeets, 2011; Yeung, 2018; though see also Nijs & Franken, 2012). That said, several of the brain regions that are known to be involved in attention and

adaptive food behaviour appear to track the 'ideal' meal portion rather than those that are either "too small' or "too big" (Toepel, Bielser, Forde, Martin, Voirin, et al., 2015).

2.2. Energy density, total energy, or palatability

Several studies have now provided evidence that it is the actual, rather than the perceived, energy density that is a key driver of the consumer's visual attention (and preference). Furthermore, it is the actual, not the estimated, caloric density of food that correlates positively with the willingness-to-pay and activities in the value-related regions (DiFeliceantonio et al., 2018; Tang et al., 2014). Given that the consumer's visual attention appears to be attracted to food imagery in relation to the total energy, or energy-density, of the food presented visually, it would therefore seem to make sense for food advertisers to display as much food (or energy) as possible in their marketing communications.

That said, it might be worth considering whether it is food palatability, rather than quality, that is actually key to capturing the consumer's visual attention (e.g., Liu, Roefs, & Nederkoorn, 2021; Motoki, Saito, Nouchi, Kawashima, & Sugiura, 2018). Liu et al.'s study is somewhat ambiguous in this regard. That is, it is unclear whether it was the attractiveness of the food shown, or the attractiveness of the food images themselves, that the participants were actually rating (and which was correlated with visual attentional capture). If the distinction here sounds subtle, note only how the dissociation between the beauty of the food imagery and the quality of the component ingredients was effectively highlighted by the work of internet-sensation Canadian Chef Jacques La Merde a few years ago (Galarza, 2016). The chef deliberately made a number of beautiful plates of food out of highly processed foods that one could pick-up from the gas station, say (e.g., crushed Doritos and Cheez Whiz). The chef's aim in this case was presumably to emphasize the fact that we should not always be led by our eyes. Thus, while there is broad consensus in the literature that energy density is a key driver of people's visual attention (see Motoki, Satio, & Onuma, 2021, for a review), it is not always clear whether it is the perceived, or actual, energy context (or even the palatability; Yeomans, Blundell, & Leshem, 2004) that is key.

2.3. Biased estimates of food quantity

The consumer's estimates of the quantity of food represented visually tend to be prone to error (Tal, Gvili, & Amar, 2021; Woolley & Liu, 2021). For instance, Tal et al. recently demonstrated that simply displaying a larger visual image of a soft drink to the participants in one online study led to the latter's estimating the calorie content as being higher. (One might, of course, want to question how well such explicit judgments would map on to an individual's implicit judgments of energy-density.) In another relevant study, participants shown plates of tomato and mozzarella salad with the food either spread-out or else stacked-up in a tower, preferred the former arrangement (see Rowley & Spence, 2018), presumably because it looked like there was more food, even though, in fact, exactly the same amount of food was displayed in both cases (cf. Szocs & Lefebvre, 2015). When the participants in a study that was published a few years ago were asked which of two visually-displayed plates of food they preferred, they exhibited a small but significant bias toward choosing the one containing more energy/food, even in those cases where there was only a minimal difference in the total amount of food shown (Woods et al., 2016).

Here, of course, one might also consider the literature on plate/rim size and background colour – giving the impression of more food, when it appears to fill the plate (Petit et al., 2018; Van Ittersum & Wansink, 2012; though see also McClain, van den Bos, Matheson, Desai, McClure, & Robinson, 2014, for a review). At the same time, however, it should also be remembered that oversized-portions of food actually reduced visual-attractiveness in the studies of Toepel et al. (2015) and Cornil and Chandon (2016). Hence, one might expect such plate-/rim-size effects to be modulated by the total amount of food shown. Taken together, therefore, the above results hint at the importance of showing the consumer as much food as possible (i.e., to maximise attentional capture).

2.4 Sharing plates and portion size estimation

It would certainly be interesting to know how people's brains process all of the food that may be shown in, for example, a sharing platter or basket advert. According to Taylor and Noseworthy (2021), food sharing reduces perceived ownership, which, in turn, leads people to mentally decouple calories from their consequence. While the viewer might intellectually recognise that the food displayed is meant to be shared (i.e., meaning that they know it is not just for one person), it nevertheless seems possible that their 'primitive' brain might simply

code all of the food shown in the image as being edible, and hence find such images, which show a far greater quantity of energy-dense, hyper-palatable food, as being highly visually-attractive. Certainly, those making food media for TV and the internet would also appear to have cottoned-on to the idea.

At the same time, however, it is important to recognize that there are often constraints on how much food can legitimately be presented, as with the serving suggestions on product packaging, which are often supposed to relate to a single person/serving, according to the guidelines (Antonuk & Block, 2006). Worryingly, the serving suggestion images that appear on food packaging (e.g., for breakfast cereals), often show as much as three times the recommended serving suggestion (Lock, 2018; Petit, Velasco, & Spence, 2018; see also Madzharov & Block, 2010). Visual images of food on product packaging may also be taken as providing a visual cue as to the appropriate portion size. This may, in turn, influence the consumer's food expectations and subsequent food behaviour (e.g., hunger, expected pleasure, purchase intention, and serving, see Madzharov & Block, 2010; Petit et al., 2018; Petit, Velasco, Spence, Woods, & Cheok, 2017; Wansink, Painter, & North, 2005).

2.5. Energy-density of recipes/foods presented in TV cookery programs and mukbang videos

The visual attention-capturing properties of energy-dense foods may also helps to explain the rise of food television in recent decades. Analysis of the nutritional qualities of the dishes created on TV cookery shows, such as MasterChef (Kirkwood, 2017), reveals that the calorie-count tends to be much higher than recommended by nutritional guidelines for people's actual consumption (Howard, Adams, & White, 2012; See also Trattner, Elsweiler, & Howard, 2017, for a comparison between TV and Internet; with the comparison not always being good for the internet). The problem is that calorie counts on food television may influence people's actual patterns of food consumption (Bodenlos & Wormuth, 2013; see also Adema, 2000; Boyland, Harrold, Kirkham, Corker, Cuddy, Evans, et al., 2011; Halford, Gillespie, Brown, Pontin, & Dovey, 2004; Lioutas & Tzimitra-Kalogianni, 2015; Liu & Bailey, 2020, 2021).

The fact that energy-dense foods are so attractive to our visual attention may potentially also help to explain the Asian cultural phenomemon known as 'mukbang' (Kircaburun, Harris, Calado, & Griffiths, 2021; see also Kircaburun, Stavropoulos, Harris, Calado, Emirtekin, & Griffiths, 2020; Kircaburun, Yurdagül, Kuss, Emirtekin, & Griffiths, 2020). There has been a

dramatic rise in popularity of this trend in the Far East in recent years (Stanton, 2015). Mukbang videos involve people, known as broadcast jockeys, eating large portions of energy-dense foods such as, for example, large bowls of fried chicken (e.g., Donnar, 2017; Kim, 2018; Pereira, Sung, & Lee, 2019; Spence, 2017a; Vice Foods, 2015), while those watching such videos at home typically eat rather more modestly. Part of the appeal of such videos, which are purportedly watched by millions in Korea and other parts of Asia, is presumably the large energy-dense portions of food that are displayed on screen (Spence, 2017a; cf. Redden & Haws, 2012; Strand & Gustafsson, 2020). Adopting an evolutionary lens, Pancer, Philp, Poole, and Noseworthy (2021) recently suggested that the valence of people's affective state varies by the implied caloric density of food media, which has a direct impact on social media engagement. For instance, Pancer et al. analysed a catalog of Buzzfeed's Tasty videos based on the nutritional content derived from the dish's ingredients and found that caloric density (i.e., calories per serving) positively influenced likes, comments, and shares on Facebook.

2.6. Dynamic food stimuli capture attention

Experimental psychologists have long known that motion captures our visual attention (e.g., Acik, Bartel, & Konig, 2014; Franconeri & Simons, 2003, 2005; Pratt, Radulescu, Guo, & Abrams, 2010). Together with the research showing that the sight of energy-dense foods does much the same (e.g., Murtarelli, Romenti, & Valentini, 2021), this presumably helps to explain the eye-appeal of what have been referred to as protein-in-motion shots (sometimes referred to as 'yolk porn'; Spence, 2017a, b). This descriptor has been used to refer to visual stimuli including oozing cheese and dribbling egg yolks, that display energy-dense stimuli in motion (Nealon, 2017; see also Hodgkin, 2016) (see **Figure 2**). See also the advertising from Carl's Junior showing an attention-capturing food in (implied) motion moment (see Turnbull, 2016).

INSERT FIGURE 2 ABOUT HERE

The British retailer Marks & Spencer's used this approach (to the incorporation of dynamic food stimuli) to make their food more visually appealing very effectively some years ago with a series of advertisements featuring, for example, an oozing chocolate pudding (Spence, 2017a; see also Ridley, 2014). The majority of food ads in the 2014 Super Bowl, these some of the most valuable, and hence expensive, advertising slots, also displayed food in motion (e.g.,

literally being thrown across the screen in one case; Gvili, Tal, Amar, Hallak, Wansink, Giblin, & Bommelaer, 2015).

Taken, together, such observations suggest that the food marketers may intuitively know about the eye appeal of food in motion. According to the marketing literature, consumers find those energy-dense foods that happen to be portrayed in motion (either actually moving, as in the case of a video, or else showing implied motion, as in the case of a static ad) as significantly more visually attractive than those foods that show food as stationary (e.g., Amar, Gvili, & Tal, 2021; Gvili et al., 2015; Gvili, Tal, Amar, & Wansink, 2017; Li & Liu, 2022; Yu, Droulers, & Lacoste-Badie, 2022). That being said, Mulier, Meersseman, Vermeir, and Slabbinck (2021) recently reported three between-participants experiments (N = 626 participants) in which they failed to find any evidence that implied motion (vs. no motion) enhancing perceived visual appeal, tastiness, freshness, or healthiness across a wide range of food products. Mulier et al.'s suggestion was that the discrepancy in results was likely caused by Gvili et al.'s studies (Amar et al., 2021; Gvili, Tal, Amar, Hallak, & Wansink, 2015; Gvili et al., 2015, 2017) being statistically underpowered; they also note how only a very limited range of food products were tested in Gvili et al.'s early studies. Unfortunately, it should probably also be noted here that the senior author on three of these publications, has had many of his publications retracted for questionable research practices (see Lee, 2019; Resnick & Belluz, 2018). Nevertheless, complicating matters somewhat, Li and Liu (2022), recently reported more pronounced positive effects of dynamic food imagery on people's taste expectations when the latter happen to have a hedonic goal in mind (i.e., focusing on the pursuit of short-term sensory pleasure). By contrast, there was no effect of dynamic food imagery for those with a hedonic consumption goal instead. Taken together, therefore, it would appear that further research is needed in order to determine the precise conditions under which implied motion makes visually-presented foods look more delicious.

2.6. Interim summary

The prediction from the cognitive neuroscience research that has been published to date for those wanting to maximise the eye appeal of food is to display as much of it as possible, and more importantly, to do whatever can be done to trick the brain into generating a higher estimate of the total amount of food present (e.g., by spreading the food out; Rowley & Spence,

2018; see also Sakay Rodriguez, Masulo, & Yamanaka, in press), i.e., by working with the biases that have been documented in portion size estimation.

3. The importance of eating simulations to enhancing a food's visual deliciousness

Ideally, according to the cognitive neuroscience research, the presentation of the food should be organised so as to make it as easy as possible for the viewer's brain to simulate the act of consuming whatever is shown (Petit et al., 2018; Petit et al., 2017; see also Petit et al., in press).

3.1. Imagining the taste/flavour of food

Many people report that they can imagine the taste, aroma, and/or flavour of food (though, that said, it should be noted that mental imagery in the chemical senses tends to be weaker than for the other senses; e.g., see Krishna, Morrin, & Sayin, 2014; Schifferstein, 2009; Speed & Majid, 2020). Nevertheless, regardless of the vividness of mental imagery in such cases, a growing body of research now suggests that our brain simulates the act of eating the food that it catches sight of (e.g., Basso, Petit, Le Bellu, Lahlou, Cancel, & Anton, 2018; Petit, Merunka, Anton, Nazarian, Spence, et al., 2016). Indeed, many researchers are increasingly of the opinion that viewing food regularly elicits elaborate neural activity associated with the viewer imagining the sensory qualities that would be expected were the food to be eaten. What is more, such eating simulations are thought to play a key role in determining the visual attractiveness of various foods (Speed et al., 2021), especially in the case of unhealthy foods (Petit et al., 2017).

Given what we saw in the previous section, one might have imagined that more pleasure would be associated with mentally simulating the consumption of a larger (i.e., rather than a smaller) portion of food. Somewhat surprisingly, however, according to research from Petit et al. (2017), it was actually the smallest portion of French fries depicted visually that give rise to the most expected pleasure in their study's participants (see also Cornil & Chandon, 2016). According to research from Brunstrom and Shakeshaft (2009), the ideal portion size is predicted both by liking and by expected satiety. People generally consider liked food and food that is more satiating to be more rewarding. They also prefer smaller portions of foods that are regarded as more rewarding. That said, repeatedly simulating the act of eating actually leads to a decrease

in the rated attractiveness of food (Larson, Redden, & Elder, 2014; Morewedge, Huh, & Vosgerau, 2010), thus perhaps akin to what is seen in the case of sensory-specific satiety.

3.2. Increased liking as a result of enhanced graspability

One of the ways in which food can be made more visually-appealing, given the mental simulations of eating that are elicited by viewing food imagery, is to make it as easy as possible for the viewer's brain to grasp, or rather to imagine grasping, the food that is displayed. Making it easier for the viewer to imagine consuming the food (e.g., by orienting the handles of any visible tableware toward the side of the viewer's dominant hand; see Elder & Krishna, 2012; Maille, Morrin, & Reynolds-McIlnay, 2020), helps to make the food displayed that little bit more attractive (see also Shibuya, Kasuga, Sato, Santa, Homma, & Miyamoto, 2022; though see also Simmonds, Woods, & Spence, 2018b). What is more, unhealthy foods have been shown to be strongly associated with the viewer's right side, presumably because they lie close to their normally-dominant hand (e.g., Romero & Biswas, 2016; see also Deng & Kahn, 2009; Kahn & Deng, 2006; Simmonds, Woods, & Spence, 2018b). Once again, it is easy to imagine how this presumably makes it that little bit easier for the brain of the right-handed viewer to simulate the act of grasping (and thereafter eating) the food that is displayed.

Relevant here, Shibuya et al. (2022) recently reported in this journal that people prefer those food images where the food was presented in an orientation that was easy to grasp by the right hand and bring to their mouth. In particular, 67% of the time when young right-handed Japanese consumers were shown pairs of foods, such as the eclairs in **Figure 3**, but also several other foods that could also easily be grasped with one hand, such as a sandwich, or a slice of pizza, they preferred the food that was shown oriented from bottom-left to top-right. In only 33% of cases did they prefer the mirror image presentation instead (i.e., with the food oriented top-left to bottom-right). Intriguingly, however, no such orientation differences were observed for tilted landscape images, suggesting that it was something special about food.

INSERT FIGURE 3 ABOUT HERE

At the same time, however, research from Maille et al. (2020) has shown that even something as simple as presenting graspable objects in the background (e.g., mugs, wine glasses, and yoghurt pots) can lead to an increase in the viewer's intention to purchase non-graspable target

products Although Maille and colleagues' study concerned non-food products, the same principles might well be expected to apply in the case of edible food products. It is, though, best not to place anything (such as objects) between the viewer and the food (Cannon, Hayes, & Tipper, 2020; Makris, Hadar, & Yarrow, 2011; McKean, Flavell, Over, & Tipper, 2020), as this will likely interfere with the viewer's embodied mental simulation of eating the food thus, in turn, reducing their liking for what they see.

3.3. Increased proximity facilitates liking

The apparent location of the food in an image with respect to the viewer also exerts a significant influence over the latter's appreciation of whatever it is that they happen to be looking at. Perhaps unsurprisingly, people tend to value those stimuli (including foods) that appear to be in their own personal space that little bit more than those that happen to be positioned elsewhere. According to Chu, Chang, and Lee (2021), this is particularly obvious in the case of popular (i.e., as opposed to luxury) brands (see also Togawa & Sugitani, in press). Placing the food close to, rather than far away, from the viewer has also been shown to lead to increased food consumption as well (e.g., Chu et al., 2021; Hunter et al., 2018; though see Wan, Qiu, & Wang, 2021, for null effects of distance in a virtual reality setting). Notice here how making the food items appear close both makes it easier for the viewer to simulate the act of eating it, and, at the same time, helps to give the impression that the food is actually in the viewer's personal space.

Displaying a close-up, first-person perspective can help to make energy-dense foods more visually appealing (Basso et al., 2018; see also Ohla, Toepel, le Coutre, & Hudry, 2012; Meersseman, Vermeir, & Geuens, 2021b) (see **Figure 4**). Furthermore, such a presentation strategy can also help to promote the idea that the foods are in the viewer's own personal space. This also helps to make foods appear more visually-appealing (see Baskin, Gorlin, Chance, Novemsky, Dhar, et al., 2016; Hunter, Hollands, Couturier, & Marteau, 2018). By contrast, make it look as though the food belongs to someone else, and the viewer will simply not rate the food that is depicted as being as visually attractive as they otherwise might (Christian, Miles, Kenyeri, Mattschey, & Macrae, 2016). Third-person (in contrast to first-person) simulations tend to result in decreased mental representation, reduced consumption, and a lower willingness to pay for desirable food items. Indeed, it has been suggested that using the third-

person perspective may constitute a particularly effective means of helping people to resist the visual temptation of unhealthy foods and thus better regulate their food intake (see Christian et al., 2016).

INSERT FIGURE 4 ABOUT HERE

3.4. The Self-Prioritisation Effect (SPE) makes food more visually-appealing

People will often say that their tea or coffee tastes better out of their favourite mug than out of someone else's (e.g., Daily Mail Reporter, 2009; Spence, 2017a). Notice how when a beverage is served in one's own mug it is very definitely 'one's own' (Spence, 2017a). One explanation for such observations is in terms of 'sensation transference' (e.g., Cheskin, 1981) from what one feels about the container to what one thinks about the contents. Indeed, another potentially relevant phenomenon as far as maximizing the eye-appeal of food is concerned relates to the Self-Prioritisation Effect (SPE; Schäfer, Wesslein, Spence, Wentura, & Frings, 2016). The relevant question here concerns how to maximise the likelihood that the viewer's brain in some sense takes ownership of the food (Kamleitner & Feuchtl, 2015; cf. Sel, Sui, Shepherd, & Humphreys, 2019). Doing so will likely increase the food's perceived visual attractiveness and motivational salience (i.e., linked to the viewer's desire to acquire/consume it). Relevant here, Sel and colleagues reported that the SPE engendered in response to those stimuli that participants had been instructed to associate with themselves was somewhat more pronounced for natural foods (e.g., banana, corn, and avocado) than for those foods that had been transformed in some way (e.g., cheese or sausages), or else for those foods that were rotten.

3.5. Interim summary

The research that has been reviewed in this section demonstrates that anything that can be done to facilitate the embodied mental simulation (of consuming) the food that is shown visually will likely increase its eye appeal. In the next section, we take a closer look at the various aesthetic factors that have also been shown to influence the appeal of images of food.

4. Visual aesthetics influence food deliciousness

4.1. Classical aesthetics features

Principles of visual aesthetics (or beauty), including balance, order, symmetry, and pattern repetition, influence the visual appeal of foods (see Hagen, 2021; Spence, 2021a). For example, the neat, or artistic (e.g., contemporary), presentation of foods has often been shown to increase people's preferences when compared to standard, or messy, presentations (e.g., Michel, Velasco, Gatti, & Spence, 2014; Reimann, Zaichkowsky, Neuhaus, Bender, & Weber, 2010; Van Doorn, Colonna-Dashwood, Hudd-Baillie, & Spence, 2015; Zellner, Loss, Zearfoss, & Remolina, 2014; Zellner, Siemers, Teran, Conroy, Lankford, Agrafiotis, Ambrose, & Locher, 2011; Zampollo, Kniffin, Wansink, & Shimizu, 2012a). Similarly, people generally prefer a balanced visual presentation of the elements on the plate to an unbalanced one (Velasco, Michel, Woods, & Spence, 2016; see also Schifferstein, Kudrowitz, & Breuer, 2020; Zellner et al., 2010), even though the asymmetric presentation of food is associated with the perception of increased culinary creativity (see Roque, Guastavino, Lafraire, & Fernandez, 2018a; Szocs & Lefebvre, 2015).

A growing body of empirical research from the emerging field of gastrophysics has capitalised on classical aesthetics features such as balance (Velasco, Michel, Woods, & Spence, 2016; Velasco & Veflen, 2021; Zellner, Lankford, Ambrose, & Locher, 2010), pattern repetition (Lee & Lim, 2022), and horizontal/vertical alignment (e.g., Spence, Michel, Youssef, & Woods, 2019; Velasco, Adams, Petit, & Spence, 2019) to help create the most visually-attractive food presentations. The latest research demonstrates that visually presenting the food in accordance with classical aesthetic principles features (e.g., order and symmetry, pattern repetition, or symmetry and balance) leads to the perceived healthiness of food increasing (see Hagen, 2021). Surprisingly, though, although many chefs are taught that plating an odd number of elements looks more visually-attractive that when an even number of elements are plated, the research conducted on more than 5,000 people who attended the Cravings Exhibition held at London's Science Museum a few years ago (or else who to part by visiting the associated website) revealed that people do not necessarily exhibit a visual preference for odd over even numbers of elements on the plate (see Woods, Velasco, & Spence, 2016). Rather, people showed a tendency to pick the plate that appeared to show slightly more food (see **Section 2**).

4.2. Food orientation influences eye-appeal

Researchers have demonstrated that displaying a dish with a dominant linear element ascending to the right (e.g., rather than ascending to the left), tends to be preferred (Spence, 2019; Spence, Michel, Youssef, & Woods, 2019). In fact, a number of studies of both painting and plating have now highlighted just such a bias (e.g., Youssef, Juravle, Youssef, Woods, & Spence, 2015). Returning to the study from Shibuya et al. (2022) that was described a little earlier, one might wonder whether their findings would not be better accounted for in terms of an aesthetic preference for linear elements that ascend to the right (rather than left) on the plate (but also in the aesthetics of painting; see Spence, 2021a, for a review). Unfortunately, however, in the absence of any kinematic data concerning the relative ease of grasping foods in different orientations, it is simply not possible to discriminate this account from the aesthetic preference for linear elements that ascend to the right. At the same time, however, it is worth noting how both accounts may actually explain at least some of the data (that is, they should not be treated as mutually exclusive).

Elsewhere in the literature, it has been shown that having angular food forms, such as a slice of cake or pizza, point away from the diner helps to make food look more visually appealing (Michel, Woods, Neuhäuser, Landgraf, & Spence, 2015). For instance, in online research reported by Shen, Wan, Mu, and Spence (2015), the angle at which triangular foods such as a slice of pizza, or chocolate cake, were shown subtly influenced people's preferences. In particular, downward-pointing food was rated as being significantly less pleasant, less liked, and less familiar than when exactly the same food pointed upwards instead. Such insights are, of course, are also relevant for chefs and wait staff. Silly though it may sound, the brain's fear circuits tend to be activated whenever we catch a glimpse of something angular pointing towards us, even if it happens to be something as innocuous as a slice of pizza or cake. The suggestion from the evolutionary psychologists in this case is that the primitive brain considers something angular pointing toward us as a possible weapon that could be dangerous (Spence, 2017a).

4.3. Shape

Shape features can influence people's evaluation of food (e.g., Fairhurst, Pritchard, Ospina, & Deroy, 2015; Meersseman et al., 2021a; Velasco, Woods, Petit, Cheok, & Spence, 2016). Most

of the research that has been published to date has chosen to contrast round- vs. angular-shaped food presentations (e.g., Baptista, Carvalho, Efraim, Silveira, & Behrens, 2022; Fairhurst, Pritchard, Ospina, & Deroy, 2015; Wang, Reinoso Carvalho, Persoone, & Spence, 2017; Wang, Zhang, & Jiang, 2022; Zhou, Chen, & Li, 2021; though see also Piqueras-Fiszman, Alcaide, Roura, & Spence, 2012; Zhang, Qian, Wu, He, Zhang, Yan, & He, 2022). For example, Fairhurst and colleagues manipulated the shapes (round vs. angular) of the beetroot jellies presented to their participants, as well as the shape of the plate on which they were presented (again, round vs. angular). Intriguingly, the participants rated the food as tasting sweeter when it was presented in a rounded format, and/or on a round plate, than when presented in an angular format and/or served on an angular plate instead (cf. Piqueras-Fiszman et al., 2012).

Elsewhere, Wang et al. (2017) reported that while people expected a rounder chocolate to taste sweeter than an angular-shaped chocolate, this shape-based taste expectation did not always carry over to influence the actual tasting experience. Nevertheless, to the extent that food deliciousness is based on the taste/flavour expectations that are set visually, such results are undoubtedly still relevant to the theme of the present review. The latest research from Baptista et al. (2022) comparing people's ratings of chocolate in different shapes (round vs. angular) revealed that those tasting the rounder chocolate rated it as creamier/sweeter than the square-shaped chocolate. According to another strand of shape-based food research, preferences for indulgent/hedonic foods tends to increase when the food is round, whereas healthy foods tend to be preferred when they are presented in an angular shape instead (Wang, Zhang, & Jiang, 2022; Zhou et al., 2021; see also Gopnik, 2012; and Loebnitz & Grunert, 2015, on shape abnormality and people's food preferences).

4.4. On the eye-appeal of colour variety in a meal

Colour variety would appear to be a visually-appealing property of many foods (e.g., König, Koller, Villinger, Wahl, Ziesemer, Schupp, & Renner, 2021; König & Renner, 2018; Paakki, Aaltojärvi, Sandell, & Hopia, 2019; Paakki, Sandell, & Hopia, 2019; see also Lee, Lee, Lee, & Song, 2013). Colourfulness has been highlighted as one of the important visual aesthetic features of food (Paakki et al., 2019). According to the latter researchers, it may have an especially significant role in the context of salads (cf. Spence, 2020). That said, increased colour variety is presumably also more visually-attractive in the context of other healthy foods

too. Regardless of the meal type, though, the suggestion from König et al. (2021) is that more colourful meals tend to contain a greater proportion of vegetables. At the same time, it has also been suggested that the more colourful the meal, the greater the proportion of healthy food consumed (König & Renner, 2018, 2019). Potentially relevant here, trichromatic colour vision may even have evolved to facilitate frugivory and/or folivory, specifically to help identify reddish fruit or leaves, respectively (Allen, 1879; Bompas, Kendall, & Sumner, 2013; Foroni, Pergola, & Rumiati, 2016; Sumner & Mollon, 2003).

König et al. (2021, p. 1) suggested that: "The "colourful = healthy" association can be generalised across meal types and thus may be a promising strategy to promote a healthier diet." That said, it may be sensible to insert a note of caution here before generalizing from the results of a single study involving very specific conditions (e.g., stimuli, participants, etc.) without further empirical support. Furthermore, it should also be noted that as far as colour variety in food is concerned, people also tend to consume more candy when it happens to be presented in a variety of colours rather is uniform in visual appearance (see Piqueras-Fiszman & Spence, 2014, for a review). Hence, while colour variety can undoubtedly increases the eye-appeal of a range of different foods, the question of whether this promotes healthy eating or not really depends on the food in question.

4.5. Conveying freshness visually

A hint of green herbs (i.e., garnish) etc. can help to convey the notion of a freshness to the visual representation of food, and thus make the displayed food appear a little more delicious (Kokaji & Nakatani, 2021; Spence, 2017a; see also Roque et al., 2018b, for a consideration of freshness in the context of beverages). As we saw earlier, some studies have identified that food in motion (be it real or implied motion, as when showing the juice on the packaging being poured into the glass in an image that is itself static) increases perceived freshness (e.g., Amar et al., 2021; Gvili et al., 2015, 2017; though see Mulier et al., 2021, for null results of implied motion on food attractiveness).

Another important way in which freshness can be conveyed visually is by means of the presence of glossiness in food images (Bailey, 2017). In fact, the luminance distribution of the foods displayed in food images appears to be an especially important feature when it comes to conveying the freshness of fruits and vegetables (Arce-Lopera, Masuda, Kimura, Wada, &

559 Okajima, 2012, 2015; Wada, Arce-Lopera, Masuda, Kimura, Dan, Goto, Tsuzuki, & Okajima,
560 2010; see also Murakoshi, Masuda, Utsumi, Tsubota, & Wada, 2013). For example, Arce-
561 Lopera et al. (2012) observed that people are able to accurately estimate the freshness of
562 strawberries using just luminance information (i.e., independent of any colour cues). One might
563 wonder if the same is also true in the case of fried foods? Consider here only how *Sampuru*
564 (the name given to Japanese fake food) so often effectively conveys a notion of glossiness
565 (Anon. 2019), presumably because this is both an eye-catching and visually-appealing food
566 cue.

567

568 *4.6. Interim conclusions*

569 In the research that has been reported in this section, a wide range of visual aesthetic factors
570 have been shown to influence the visual deliciousness of food images. It is now time to turn,
571 albeit briefly, to examine the food extrinsic visual influence that have also been shown to
572 influence the eye-appeal of food, such as background colour, lighting, and visual context.

573

574 **5. On the importance of the visual background/illumination**

575 *5.1. Colour contrast and colour priming*

576 The colour (contrast) of the background against which a food is presented has been shown to
577 influence how visually-appealing various foods/dishes look (e.g., Howell & Schifferstein,
578 2019; Kpossa & Lick, 2020; Schifferstein, Howell, & Pont, 2016; Wan et al., 2021; see Spence,
579 2018a, for a review). At the same time, however, background colour cues can also prime
580 associated concepts. For example, red plateware can inhibit people's desire to consume various
581 unhealthy foods (e.g., see Bruno, Martani, Corsini, & Oleari, 2013; Reutner, Genschow, &
582 Wänke, 2015). In this context, the suggestion from a number of researchers is that the colour
583 red may serve to trigger avoidance motivation (though see also Steele & Rash, 2021). At the
584 same time, however, Tu, Yang, and Ma (2016) demonstrated that red plateware can also help
585 to make moderately spicy tofu taste a little spicier. Elsewhere, a red background has been
586 associated with (increased) sweetness instead. Perhaps the best way in which to reconcile such
587 divergent findings may be in terms of 'colour-in-context' theory (Elliott & Maier, 2012).

According to the latter account, the meaning that people associate with a particular colour (in this case, a background colour) is often determined by the particular context in which it happens to be presented. So, red may be associated with chilli in the context of spicy foods but with sweetness in the context of a dessert.

Cheskin (1951, pp. 97-98) anecdotally reported that a green salad should be presented on a complementary colour, namely a cool red or, better still, a cool pink plate which expresses delicacy and subtlety. For bread, well it depends on the type, Cheskin suggested that blue, green, and green blue should all work. Meanwhile, he recommends serving butter on green-blue or blueish-white to bring out the richness of the dairy product. Elsewhere, Howell and Schifferstein (2019) demonstrated that visual attractiveness ratings for a range of vegetables were highest when they were presented against a darker (rather than a lighter) background.

Harrar, Piqueras-Fiszman, and Spence (2011) reported that blue and white bowls slightly enhanced the perceived saltiness of popcorn. Meanwhile, Piqueras-Fiszman et al. (2012) reported that a strawberry mousse was rated as tasting significantly sweeter, more flavourful and more liked when served off a round white plate than from a round black plate instead. In fact, in the decade or so since these results were published, numerous other studies of plate, bowl, and cup colour have been reported (see Spence, 2018a, for a review). That said, what constitutes the most appropriate background colour may, though, sometimes change as a function of an individual's age. For example, according to the findings of research by Brunk and Møller (2019), children (under 10 years of age) prefer chromatic rather than achromatic (white/black) plates, while the opposite is true for adults (and those children above 10 years of age; though see also Spence, 2017a, for the use of chromatic plateware amongst the elderly).

5.2. Packaging colour

The background colour of packaging can also exert a significant effect over people's ratings of visual deliciousness of food products (Mai, Symmank, & Seeberg-Elverfeldt, 2016; van der Laan et al., 2011 for a review). For example, explicit sensory expectations and perceptions, as well as implicit ratings of food attractiveness, tend to be higher for healthier food alternatives when packaged in warmer, saturated, and less bright colours (Tijssen, Zandstra, de Graaf, & Jager, 2017; see also Kunz, Haasova, & Florack, 2020; and Spence & Velasco, 2019, for a review). Meanwhile, Baptista, Valentin, Saldãna, and Behrens (2021) recently reported that the

colour of the packaging had contrasting effects on their participants' expectations concerning milk and dark chocolate. In particular, while their participants expected to like milk chocolate more when it was presented in dark/cold coloured-packaging, they expected that they would like dark chocolate more when it was shown packaged in bright warm colours instead (see also Kovač, Kovačević, Bota, & Brozović, 2019; Sugimori & Kawasaki, 2022).

It is, though, not just the outer packaging colour that matters though. It has, for example, been shown that the visual appearance of the food product against the inner packaging may also be important as far as determining the eye-appeal of food products is concerned (see van Esch, Heller, & Northey, 2019). Presumably this is even more likely to be the case for those foods that are consumed direct from the packaging. Optimizing colour contrast between product and packaging also seems key to maximizing deliciousness here.

5.3. Visual background/context

The background situation/context can also play an important role. For instance, Papies, van Stekelenburg, Smeets, Zandstra, and Dijksterhuis (2022) demonstrated that when a food image is presented in a congruent situation then it is processed more fluently and this can give rise to an increased expectation of liking the food and desire, as compared to an incongruent situation (discussed earlier). Further analysis suggested that this visual context effect was partially (or fully) mediated by eating simulations. The congruent situation was also shown to increase salivation (cf. Spence, 2011). At the same time, however, others have argued that it is important to keep the background as uniform (and uncluttered) as possible, because this may also help to make the food itself appear more visually-attractive (e.g., Brown & MacLeod, 1997; Victor, 2015; see also Wang, Ma, Chen, Ye, & Xu, 2020). It is, though, also worth noting that, as the background context becomes more salient, people's visual attention toward the food itself may be decreased (Zhang & Seo, 2015).

5.4. Lighting

The way in which a food display is illuminated contributes to its visually-perceived deliciousness. For instance, warm lighting (yellow light around 3,000K) leads to foods being

rated as more appealing as compared to regular daylight (c. 5,600K) and both (food in warm and regular lightning) are rated as more visually–appealing than when shade/blue light (c. 9,500K) is used instead (Sakay Rodriguez et al., in press; see also Tsujimura & Yanagisawa, 2015). Ambient lighting has also been shown to alter the consumer's motivational responses (e.g., meaning their desire to acquire/consume the food) to advertisements for foods of different energetic value (Bailey, Wang, & Liu, 2021a). The ambient lighting levels in those places where food images are viewed may also influence the viewer's motivation to acquire the food, as well as their preference for energy-dense foods (which is apparently higher in those environments that are bright; see also Bailey, 2015, 2016; Bailey et al., 2021b; though see Biswas, Szocs, Chacko, & Wansink, 2017; Chan, 2022, for results suggesting that lighter environments may actually encourage healthier food choices instead).

5.5. Interim summary

The research that has been reviewed in this section shows that the background against which food is presented (both in terms of background colour and context) can exert a significant influence over the eye-appeal of the food. Optimising the lighting and visual background are, of course, also important when it comes to maximising people's appreciation of food in the context of fine dining (e.g., Bschaden, Dörsam, Cvetko, Kalamala, & Stroebele-Benschop, 2020; see Spence, 2017a, for a review). In the next section, we will take a closer look at some of the latest digital means of manipulating food imagery to enhance a food's visual deliciousness/attractiveness.

6. Digital visual manipulation of food imagery: From Instagram to food photography

In recent years, the possibilities for many of us to digitally interact with food/food imagery have become increasingly advanced (see Barbosa Escobar, Petit, & Velasco, 2021; Bridge, 2018; Coary & Poor, 2016; Petit et al.,2019, Velasco, Obrist, Petit, & Spence, 2018; Zhang, Chen, Huang, & Wan, 2019; Zhao, Huang, Spence, & Wan, 2017). Furthermore, new visual-enabling technologies, such as VR and augmented reality (AR), are now being used to develop realistic contextual environments in which to conduct food sensory evaluation research (e.g., Xu, Siegrist, & Hartmann, 2021). For example, Barbosa Escobar et al. (2021) recently virtually

manipulated the environment in which their participants drank coffee. They were able to document a positive effect on the perception of coffee premiumness and their participants' enjoyment of the experience. Other researchers, meanwhile, are now using VR to help understand the role of visual background/illumination on the eye-appeal of food (e.g., Alba-Martínez, Sousa, Alcaniz, Cunha, Martínez-Monzó, & García-Segovia, 2022). Research from Park, Choi, and Rhee (2021) has shown that telepresence in VR affects the perceived quality of food, the perceived value price, and the purchase intention. The key point to note is that the visual appeal of food can also be modified digitally.

6.1. Digitally modifying the appearance of food itself

There is growing research interest in modifying the appearance of the food itself in a mixed reality setting (see Okajima & Hojo, 2017; Petit et al., in press; Ueda, Spence, & Okajima, 2020). Mixed reality environments offer a host of new ways in which to interact with food that may end-up affecting people's evaluation. To give a sense of the possibilities in this space, Petit et al. (in press) highlighted that perceived interactivity with food (zoom in and rotate the image of the dish) is better in 3D-visualisation than in AR, which increases immersion and further leads to higher mental simulation of the eating process for packaged food. Note here how by using dynamic food images, marketers can increase a person's ability to generate mental simulations of transformation, rotation, and the reorganisations of the imagined product with a carry-over positive effect on its evaluation (see Cian, Krishna, & Elder, 2014).

Adding a steaming or boiling effect provides another effective means of increasing the eye-appeal of food imagery (Suzuki, Narumi, Tanikawa, & Hirose, 2021). This is an area that the Ajinomoto Corporation (from Japan) have been interested in for several years now. Suzuki and colleagues demonstrated that the addition of dynamic boiling imagery to a food display (created by means of the projection mapping; see also Fujimoto, 2018) increased their participants' appetite ratings before and after eating in comparison with when the food image was presented without such dynamic visual augmentation. Meanwhile, Nishizawa, Jiang, and Okajima (2016) have used projective-AR to enhance the eye-appeal of foods such as sponge cake and potato chips. Meanwhile, Ueda et al. (2020) varied the standard deviation of the luminance on the appearance of two foods, Baumkuchen and ketchup, and highlighted a significant effect on people's flavour expectations, and taste/flavour perception.

Here, one might wonder whether part of the appeal of carbonated drinks also comes from the sight of the bubbles in motion as they ascend in the glass (see Roque, Lafraire, Spence, & Auvray, 2018b). Taken together, therefore, it would appear as though certain kinds of dynamic visual imagery (i.e., be it the food itself that is moving or merely the stream rising from hot food or drink, or the effervescence rising) is likely going to be rated as more visually attractive (though, there are, of course also exceptions; Spence, 2018b). Given that digital techniques exist to add both steaming effects and carbonation to food images it is thus possible to enhance visual deliciousness in a predictable way (e.g., Roque, Lafraire, & Auvray, 2020; Okajima & Hojo, 2017).

6.2. Recommendations from digital food photography

There is a separate literature associated with the visual tricks used by food photographers to help enhance the appeal of food photography (Kakimori, Okabe, Yanai, & Onai, 2015), including gastroporn images (Sakay Rodriguez et al., in press). While, traditionally, insights often came from professional food photographers (e.g., Anon., 2013; Victor, 2015), the last few years has seen a growing interest in the use of image filters to help make existing food images more attractive to regular consumers (e.g., Sakay Rodriguez et al., in press).

Taken together, it is thus intriguing to notice how the emphasis in the research is shifting beyond the mere conveying of the energy-density of what is shown to a more aesthetic consideration of how a given range of elements are displayed. The appeal in such cases derives more from aesthetics than energy density. Although the calorie-density of food images are linked to social media engagement (likes, share, and comments; Pancer, Philp, Poole, & Noseworthy, 2021), aesthetics elements appear to capitalise on increasing the visual appeal of food photography and its impact on social media engagement (see also Qutteina, Hallez, Mennes, De Backer, & Smits, 2019). Separately, there is interest in the visual appeal of symmetrical foods (e.g., see https://www.symmetrybreakfast.com/). Combinations of some aesthetic manipulations (e.g., order plus symmetry, pattern repetition, and symmetry plus balance) can also be used to increase the perceived healthiness of food (see Hagen, 2021). Those serving food in a hospitality setting would obviously also be well-advised to keep such findings in mind.

740 *6.3. Looking at food versus at an image of food*

741 Given such differences between viewing actual foods versus looking at the reproduced image
742 instead, the focus of the present review (as for the majority of the literature) will primarily be
743 on still and dynamic images of food in pictures and/or visual advertisements. Here, when
744 considering the digital manipulation of food, it is perhaps worth noting that the consumer's
745 brain responds somewhat differently as a function of whether or not the food that is visible
746 actually happens to be present/edible (e.g., Blechert, Klackl, Miedl, & Wilhelm, 2016; see also
747 Spence, 2011, for a review of this distinction, specifically with regard to salivation). This may,
748 for example, help to explain why making food visible by means of transparent windows in
749 product packaging captures the consumers' attention and increase their preferences more
750 effectively than the use of food images on the front of packaging (e.g., as compared to food
751 imagery on the front of pack; see Simmonds, & Spence, 2017, 2019; Simmonds, Woods, &
752 Spence, 2018a; Smith, Barratt, & Sørensen, 2015; see also Capelli & Thomas, 2020), especially
753 when the food is small and visually attractive (Deng & Srinivasan, 2013). Notice how, in the
754 case of those other foods, or ingredients that may not look so appealing, or may look messy,
755 then product imagery may be a more appropriate approach for those wanting to maximize food
756 deliciousness visually.

757 Recently, there has been something of an upsurge of interested in unusually coloured foods
758 (e.g., see Burger King Black or Red Burgers; Anon., 2015), in part, presumably because of
759 their Instagrammability (see Whittle, 2018, on this theme). And while it is easy to believe that
760 the public's fascination with colourful foods is no more than a passing contemporary trend, it
761 turns out that the public's desire for brightly-coloured foods has actually been traced back
762 several centuries (Woolgar, 2018).

763 Nevertheless, the sudden risen in popularity of blue foods is something that has happened in
764 the last decade or so (Spence, 2021b). However, it is interesting to note how this food colour
765 tends to appear far more frequently in digital food images rather than necessarily in the dishes
766 served in restaurants. This then perhaps points to an intriguing dissociation between those
767 dishes that merely have eye-appeal, and are Instagrammable and those that also taste good.
768 Such a dissociation may be hard to square with attempts to use image analysis techniques in
769 order to try and computationally analyse/predict the deliciousness of food images (see
770 Takahashi et al., 2019). At the same time, however, black and white, rather than colour, images

of food appear to be rated as significantly less appealing despite presumably portraying exactly the same food (Del Gatto, Indraccolo, Imperatori, & Brunetti, 2021; see also Sato, 2021).

6.4. Interim summary

The extensive literature that has been published to date on the visual (re-)presentation of food clearly demonstrates that a large number of factors influence the way in which the food, be it presented visually in food photography, food advertising, or on Instagram, in Mukbang videos, on food television, and/or chef-related food/cooking apps (e.g., such as Chef Steps, https://www.chefsteps.com/), can be made to look more appealing (Kokaji & Nakatani, 2021; Peters, 2014; Spence, 2017b). Nevertheless, it would currently seem to be something of an open question as to whether digital foodporn can ever be used to help prime healthy eating (Kang, Lee, Kim, & Yun, 2020; Petit, Oullier, & Cheok, 2016; Seal, Gavaravarapu, & Konapur, 2022). At the same time, however, it is interesting to note how visual deliciousness sometimes dissociates from delicious-tasting food in the digital sphere. One of the key points to note here is that food advertising is simply not like other kinds of product advertising. Indeed, as the famous German philosopher Immanuel Kant (1892/1951) highlighted long ago, the viewer cannot maintain a disinterested state when confronted with food, even when depicted in an advert, picture, or painting (see Spence, 2021a). As J. Z. Young (1968), put it more than half a century ago, the brain has, in some sense, evolved with food/sustenance very much top of mind, and vision is probably the most effective of the consumer's distal senses when it comes to locating and tracking energy-dense foods.

7. Conclusions

According to the Young (1968), the brain evolved with food in mind. Consistent with such a view, contemporary cognitive neuroscience research has demonstrated the increases in cerebral blood flow that are often associated with the desirability of food when they are hungry (van der Laan et al., 2011, for a review). Indeed, the human brain rapidly determines the energy-density of foods that happen to be visible in a scene, and thereafter directs its attentional resources accordingly (e.g., Sawada et al., 2019). The taste qualities associated with images of food are rapidly computed (e.g., Crouzet, Busch, & Ohla, 2015), and flavour expectations

generated, in part via embodied mental simulations. Food-related visual cues can trigger physiological responses in the viewer, such as salivation (Spence, 2011; euphemistically called a 'mouthgasm', Capel, 2015), and the preparatory release of gastric juices (to facilitate the digestion of the anticipated food consumption; Hou, Mogg, Bradley, Moss-Morris, Peveler, & Roefs, 2011).

Embodied mental simulation has been a recurrent theme in this review, with the research showing that the human brain simulates the act of eating whatever it sees (Papies et al., 2021; Petit et al., in press). In fact, a growing body of cognitive neuroscience research suggests that our brains not only compute the energy-density of the food displayed visually, but also engage more-or-less automatically in simulating the act of grasping/consuming the food (see Basso et al., 2018). What is more, we appear to like those (food) stimuli that we find it easier to interact (or even simply just imagine interacting) with, such as grasping a sandwich (Shibuya et al., 2022; though see also Spence, 2022c), or picking up a mug with the handle directed toward our dominant hand (Elder & Krishna, 2012).

Anything that makes it easier for the viewer's brain to simulate the act of grasping/consuming the food that is shown helps to make the latter look more visually delicious. At the same time, however, the growing interest in 'gastroporn' (otherwise known as 'food porn') means that many of the visual depictions of food that consumers are exposed to nowadays appeal as much at an aesthetic as at a purely energetic level. Taken together, the evidence that has been critically evaluated in this narrative historical review (backed-up by PRISMA-reporting protocol), supports the view that a variety of visual cues connected to the presentation/display of food influence people's food behaviours in a multitude of ways. What is clear is the human brain rapidly computes the energy-density of food displayed visually, no matter whether it is physically present in front of the viewer, or is merely an image of food, be it represented digitally (e.g., on the internet, in Instagram, Mukbang, cookery shows, etc.), or else in print (e.g., in a traditional food advertisement, or perhaps printed on the front of food packaging; Simmonds & Spence, 2019). Visual attention is directed to the more energy-dense food elements in the scene (e.g., Sawada et al., 2017).

Given the research that has been reviewed here there are clearly a number of routes to increasing visual-deliciousness of food images. On the one hand, anything that can be done to increase the actual, or even just the perceived energy-density of the food (the latter achieved, for example, by spreading the food out rather than stacking it up, or by using smaller plates and

possibly also rimless bowls) will likely lead to increased visual deliciousness. On the other hand, beyond the energy density represented by a given food (image), there is growing evidence that a host of other visual aesthetic factors may also influence rated food attractiveness/deliciousness. These include everything from symmetry and balance, and from colourfulness to the glossiness etc. of the food displayed. Importantly, marketers, advertisers, and those creating online food content would all appear to have intuitively picked-up on at least certain of these features. Nowadays, a range of digital-enhancing technologies enable people to augment digital images of food in ways that may help to make food images more attractive (e.g., Petit, et al., in press).

The focus of the present review has been on ways in which to make food more visually-attractive, or delicious rather than to make the food look more sustainable or healthier. As such, we have not looked at ways to make the food look more sustainable. The behavioural and cognitive neuroscience research that has been published to date clearly demonstrates that the appeal of a given portion of food can vary as a function of how exactly it is presented: Everything from the viewing angle at which the food is shown (e.g., Michel et al., 2015; Takahashi, Hattori, Doman, Kawanishi, Hirayama, Ide, Deguchi, & Murase, 2019; though see also Sakay Rodriguez et al., in press) through to the layout/orientation of the food on the plate or meal tray/basket/platter (e.g., Michel, Velasco, Gatti, & Spence, 2014; Saner, 2015), and from the background against which the food happens to be presented through to the level of lighting in the food image (Howell & Schifferstein, 2019; Spence, 2018a), or even in the environment in which that food image is being viewed (e.g., Papies, van Stekelenburg, Smeets, Zandstra, & Dijksterhuis, 2022). In fact, according to the research that has been published to date, it all appears to make a difference. While a number of the suggestions might appear intuitive, others certainly are not (such as the suggestion to plate odd rather than even numbers of elements on the plate; Woods et al., 2016). The data concerning the benefits of the implied motion of food stimuli are also still a little unclear.

However, there are various other aims that should perhaps be considered here. These include creating visual content that is not just delicious, but also memorable (Spence, 2022a). Creating food imagery that helps to keep the food brand top of the consumer's mind should not be ignored either (see Romaniuk & Sharp, 2016). Delivering maximally Instagrammable 'food porn' (McBride, 2010; Whittle, 2018) has become the goal for some, although 'likes' or 'shares' might provide a more intriguing measure of the appeal of a given dish (see also Andersen,

Byrne, & Wang, 2021; Pancer et al., 2021).) To trigger maximal food cravings (Fletcher et al., 2007; Spence, 2012; Wang et al., 2004). To look as delicious, or appetising, as possible (Glyda, 2019; Sakay Rodriguez et al., in press); Optimizing colour variety would also appear to be a worthy aim (König et al., 2021; Paakki et al., 2019).

One of the other points to have emerged from this systematic narrative review is that the viewer's response to various visual features of a food display often hinges on whether the food is natural vs. transformed foods (e.g., Sel et al., 2019); Unhealthy vs. healthy (Petit et al., 2017; Romero & Biswas, 2016); Energy-dense or not (Basso et al., 2018); Vice or virtue food (Huang, Wang, & Chan, 2022); Hedonic or functional foods (Zhou et al., 2021).

Of course, while the research that has been reviewed here has attempted to optimize visual food deliciousness, it should be noted that an important challenge in terms of sustainability concerns how to encourage more consumers to embrace ugly produce (Pfeiffer, Sundar, & Deval, 2021). While the available science provides more or less robust tips concerning how to optimise any one of these outcomes in response to the presentation of specific food images, the link to the consumer's (repeat) purchase behaviour is currently unclear from the academic literature (though see also Suzuki et al., 2021, for an isolated exception). This may simply reflect the fact that it is difficult to conduct such studies over the longer term in the marketplace.

The research that has been published to date is also rather unclear about whether similar effects to those documented here in response to the sight of food could potentially be elicited in response to the smell (Spence, 2022b), and/or sound of food and/or its consumption (Spence, 2015; Wheeler, 1938; Yeoh & Allan, 2020). Although humans are visually-dominant creatures (see Hutmacher, 2019), extending the various research outlined here to non-visual food cues represents an intriguing direction for future research. A further important issue for future research will be to assess the role of cultural differences in determining the visual attractiveness/deliciousness of food (e.g., see Hildebrand, Harding, & Hadi, 2019; Peng, Adam, Hautus, Shin, Duizer, & Yan, 2017; Zampollo, Wansink, Kniffin, Shimuzu, & Omori, 2012b). Intriguingly, however, when we have directly assessed the impact of plateware/glassware on the attractiveness of food with multiple populations from different parts of the world, we have mostly found similar results (e.g., Wan, Woods, Jacquot, Knoeferle, Kikutani, & Spence, 2016). This is perhaps not so surprising when one considers the importance of energy-density and of aesthetic principles such as balance, symmetry, and repetition, which appear to be universally liked (see Spence, 2021a). Here, of course, one might also be tempted to consider latest findings

suggesting cultural similarity in terms of ratings of odour pleasantness (Arshamian et al. 2022). Undoubtedly there must be some important cultural differences in terms of the factors driving visual deliciousness. Nevertheless, this is likely a major challenge for future research to elucidate such differences as exist. For now, the consistency of the findings that have been documented in those studies conducted across a range of western countries is reassuring.

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FIGURE LEGENDS

Figure 1. The follow chart of our literature search according to PRISMA principles.

Figure 2. Yolk porn with implied proteinaceous motion shown from a first-person perspective.

Figure 3. One of the food images presented to participants in Shibuya et al.'s (2022) recent study of the influence of food graspability on preference. The ascending-to-the-right presentation (shown on the left) was preferred over the same food when shown ascending to the left instead (shown right).

Figure 4. Visual stimuli presented to participants in Basso et al.'s (2018) neuroimaging study. (A) Unhealthy food shown from the first-person perspective; (B) Healthy food item from the first-person perspective; (C) Non-food object shown from the first-person perspective; (D) Unhealthy food item shown from the third-person perspective; (E) Healthy food item shown from the third-person perspective; (F) Non-food object shown from a third-person perspective.

Figure 1.

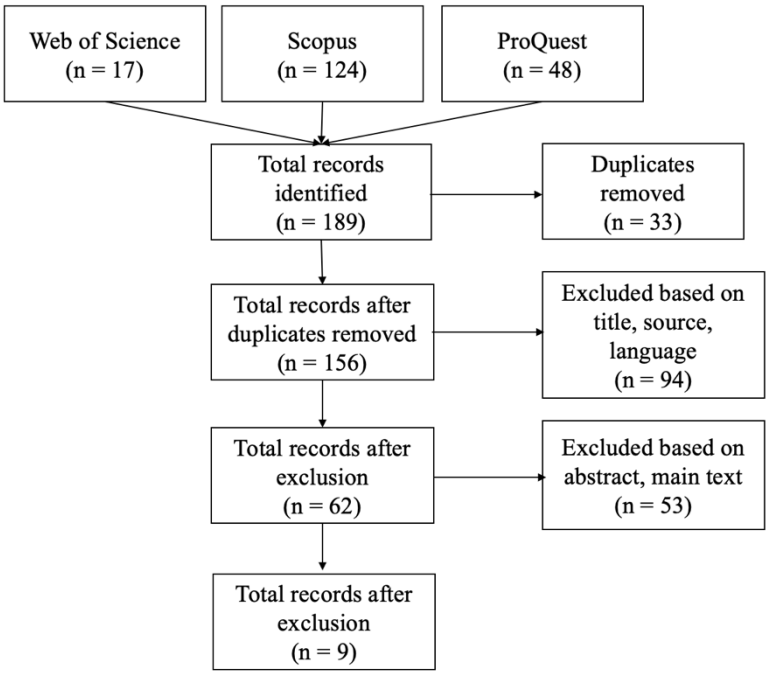

Figure 2.

Figure 3.

Figure 4.