When visual cues influence taste/flavour perception: A systematic review and the critical appraisal of multisensory flavour perception

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ABSTRACT

There has been a noticeable increase of interest in research on multisensory flavour perception in recent years. Humans are visually dominant creatures and a growing body of research has investigated how visual cues influence taste/flavour perception. At the same time, however, several null or limited findings have also been published recently; that is, studies showing either partial demonstrations or else failing to find any evidence in their data for the influence of specific visual cues on taste/flavour perception. By performing a systematic review and a critical evaluation of the literature that has been published to date, the present paper reveals whether and when visual cues (e.g., colour and shape) affect taste/flavour perception: The reviewed research shows demonstrates that visual cues can significantly affect taste/flavour perception under certain conditions, but that mixed, limited, and/or null results have also been reported in a number of other studies. We discuss potential moderators (the salience of visual cues, the strength of association between visual cues and taste/flavour, the perceived diagnosticity of visual cues regarding the signalling of taste/flavour, the evaluative malleability of food judgments) that might help to explain a number of the inconsistent findings that have appeared in the literature since 2011. Several important areas of future research in this area of inquiry are also identified.

Keywords: Vision, shape, colour, taste, flavour, crossmodal.

INTRODUCTION

Flavour perception is multisensory, with all of the senses, including vision, audition, smell, and touch potentially helping to shape the experience of flavour (Spence, 2015b). Taste perception ~~can be~~is defined as “those sensations that result from the direct simulation of the gustatory receptors localised on the tongue and occurring elsewhere in the oral cavity” (Spence, Smith, et al., 2015, p. 247; Spence, 2022b). In contrast, according to the International Standards Organization (ISO, 2008), flavour perception ~~can be~~is defined as a “Complex combination of the olfactory, gustatory and trigeminal sensations perceived during tasting.” Note, however, that in everyday language, taste is used interchangeably for flavour. As visually dominant creatures (Hutmacher, 2019; Posner et al., 1976), vision appears to be indirectly dominant in multisensory flavour perception, due to its role in helping to set~~ting~~ taste/flavour expectations that then subsequently anchor~~ing~~ the ensuing taste experience (Spence, 2015b). In everyday situations, consumers internalize flavour expectations concerning familiar foods from visual cues, be they from the food itself, the plateware or container on/in which it is presented, or any other element associated with its presentation (Spence, 2015c). Visual cues include food colour (e.g., Jeesan & Seo, 2020; Spence, 2015c), packaging shapes (e.g., Becker et al., 2011; Pleyers, 2021), logo shapes (e.g., Chen et al., 2021; Motoki et al., 2022), ambient colours (e.g., Motoki et al., 2021; Spence et al., 2014; Wu et al., 2022), cutlery colour (Harrar & Spence, 2013), plateware colour (e.g., Kpossa & Lick, 2020; Harrar et al., 2011), glassware/cup colour (e.g., Hansen, 2019; Piqueras-Fiszman & Spence, 2012), to name but a few.

Visual cues, including colour, shape, and visual texture, have received significant research attention in the context of food products; however, among these cues, colour and shape have been the most frequently studied aspects (Spence & Van Doorn, 2022). Colour and shapes have been manipulated and studied in food itself (e.g., Harrar & Spence, 2013; Fairhurst et al., 2015) as well as extrinsic to the food itself (e.g., packaging design; Veflen, Velasco, & Kraggerud, 2023). Colour and shapes in food products (e.g., the shape of food itself, colour of packaging) heanve also been shown to influence consumers' visual attention and purchasing decisions (e.g., Jaeger et al., 2018; Motoki, Saito, & Onuma, 2021; Velasco & Spence, 2019).

Colours have three primary dimensions in terms of hue (basic colour such as red, blue, green), saturation (chroma), and lightness (brightness, value; Palmer et al., 2013). Among these primary dimensions, colour hue has been most extensively studied in relation to flavour perception (Spence, 2015a, 2018; Spence et al., 2010; Spence, Wan, et al., 2015). Shape features include, for example, curvilinearity, 2D/3D shapes, and shape symmetry (see Spence, 2023, for a review). As for shape features, it appears that curvilinearity has been most extensively studied specifically in sensory and consumer science (Spence, 2023). For example, a number of studies have investigated the role of colour and shapes on flavour perception by manipulating food colour (Spence, 2015c), packaging shapes (Becker et al., 2011), typeface shapes (Velasco et al., 2018), cutlery colour (Harrar & Spence, 2013), and plateware colour (Harrar et al., 2011).

Based on the crossmodal correspondences research that emerges from a different background/tradition of research, robust evidence has accumulated suggesting that colours and shapes are reliably matched with specific tastes and flavours across a group of individuals (Spence, 2023). Crossmodal correspondences refer to “the often surprising connections that people appear to experience between simple features, attributes, or dimensions of experience, either physically present or else merely imagined, in different sensory modalities” (Spence, 2020, p. 1).

The literature on colour-flavour correspondences consistently highlights the fact that specific colours, or ranges of colour, are associated with each of the four or five basic tastes (Spence, Wan, et al., 2015). In general, sweet is widely associated with reddish/pink colours, sour with yellow/green, salty with white/blue, and bitter with black (Spence, Wan, et al., 2015). In terms of colour lightness, reddish/lighter colours were associated with sweet tastes, while greenish/darker colour were associated with sour/bitter tastes (Motoki et al., 2021). Other research shows that red is also associated with spiciness (Spence, 2019a; Spence & Levitan, 2021), suggesting that different components of the taste/flavour experience, beyond just taste (i.e., gustation, and including also trigeminal stimulants), are also reliably associated with colours. Previous studies on shape-flavour correspondences have provided robust evidence to suggest that people intuitively associate round shapes with sweetness, while connecting angular shapes with sourness, saltiness, and bitterness (e.g., Chen et al., 2018; Velasco et al., 2016). Additionally, asymmetry also appears to be associated with sourness (Turoman et al., 2018). Primary findings of visual cues-flavour correspondences are shown in Table 1.

Table 1. Primary findings of visual cues-flavour correspondences

Crossmodal correspondences	Primary findings and example literature supporting the findings
Colour-flavour	• Pink-sweet (Wan, Woods, et al., 2014) • Black-bitter (Wan, Woods, et al., 2014)

	• Green-sour (Wan, Woods, et al., 2014) • White-salty (Wan, Woods, et al., 2014) • Red-tomato (Velasco et al., 2014) • Green-cucumber (Velasco et al., 2014) • Yellow-lemon (Wan, Velasco, et al., 2014) • Green-kiwi (Wan, Velasco, et al., 2014) • Blue-blueberry (Wan, Velasco, et al., 2014) • Orange-orange (Wan, Velasco, et al., 2014) • Brown-cola (Wan, Velasco, et al., 2014)
Shape-taste/flavour	• Round-sweet (Velasco et al., 2016) • Cloud/heart/star-sweet (Wan, Woods, et al., 2014) • Angular-sour, salty, bitter (Velasco et al., 2016) • Cross/rectangle/square-bitter (Wan, Woods, et al., 2014)

Note: The table shows primary findings obtained colour hues and curvature that appear to be widely used in previous research (see also Salgado-Montejo et al., 2015; Turoman et al., 2018, for other visual features).

The concept of ‘sensation transfer’ (Cheskin, 1972) has often been used for the research on the influence of specific sensory cues, including visual cues, on flavour perceptions (Biggs et al., 2016; Kampfer et al., 2017; Sousa et al., 2020a). Sensation transference can be explained as follows: people’s feelings about sensory cues (e.g., food colour, or the feel of the packaging) can carry over to affect their evaluation about other sensory cues including taste/flavour perception (see Biggs et al., 2016). Visual cues relevant to food products are likely to induce specific expectations regarding the likely taste/flavour, which may then carry over to influence multisensory flavour perception (Spence et al., 2010).

Researchers first began to study the effect of colour on taste/flavour perception almost 90 years ago (see Duncker, 1939; Moir, 1936, for early research). However, a recent literature has developed on crossmodal correspondences that includes taste-colour/shape matches. Whilst crossmodal correspondences are often used to guide research on colour and shape influences on taste and flavour perception, the findings of the effects of visual cues on taste/flavour perception are often complex and mixed ~~in nature~~ (Spence, 2015a). Various food-relevant visual cues, including the colour of food/drinks, of food and beverage packaging, of the glassware/cup, of the plateware, of the cutlery, and of the environment, all appear capable of affecting flavour perception, at least under a subset of conditions (Spence, 2015a). The effects of colours on flavour identification would appear to be robust and well-supported (Spence, 2015a). By contrast, there would appear to be much more mixed evidence regarding the influence of visual (colour) cues on ratings of specific taste/flavour intensity (see Spence et al., 2010). The focus of this article is on the latter aspect and aims to clarify how and to what extent visual cues influence the perceived intensity of taste/flavour of foods and beverages. In particular, visual cues include food-intrinsic cues (i.e., intrinsic to the food itself like food colour, food shape), food-extrinsic factors (i.e., extrinsic to food itself such as colours and/or shapes of packaging, cutlery, lightning, ambience, containers), and mixing (or combining) these factors (see Wang, Mielby, Junge, et al., 2019). Whilst previous research has studied both the effect of intrinsic and extrinsic colour and taste cues on multisensory flavour perception, it is not clear whether both act in the same manner and the possible boundary conditions that may exist within them. As such, here, we systematically assess whether and, if so, when both food intrinsic and food extrinsic visual cues, particularly colour and shapes, influence taste/flavour perception.

Significance of the present paper

The significance of the present paper consists in ~~reveal~~suggesting a number of the conditions under which colour and shape cues influence multisensory flavor perception. This is achieved by conducting a systematic review and a critical evaluation of the literature that has been published since 2011. While a number of review papers have already been published on the topic of the crossmodal influence of colours/shapes on taste associations, expectations, and/or perceptions (Krishna & Elder, 2021; Lee & Spence, 2022; Spence, 2015a, c, 2018, 2019b, 2022a; Spence et al., 2010; Spence, Wan, et al., 2015; Spence & Levitan, 2021; Spence & Van Doorn, 2022; Van Doorn et al., 2019; Velasco et al., 2016), none of them relied on a systematic review format such as provided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines; Moher et al., 2009) framework. What is more, these previous papers exhibit a tendency to focus more on the significant results amongst the findings that have been reported in the area (though see Spence et al., 2010, for an earlier exception to this generalization). The PRISMA provides guidelines of how to include studies in the review in interns of identification and screening process (Moher et al., 2009). Based on the PRISMA guidelines, the present review systematically and critically assesses the findings reported in the literature since 2011 including significant, mixed, limited, and null results.

This paper therefore attempts to identify when and what colour/shape cues significantly affect flavour perception. With this, we contribute to the literature that has been published in English since 2011 by providing an overview of all the evidence that has accumulated in order to claim that colour and/or shape cues influences multisensory flavour perception. This review stands as one of few attempts to assess shape and colour cues as being in some sense of a similar type (i.e., both visual cues that may, or may not, influence taste/flavour perception depending on the conditions). Moreover, this review discusses possible moderators of the role of visual cues on taste/flavour perception, highlighting a number of areas for future research in this field of inquiry as well as good research practice.

METHODS

Inclusion/exclusion criteria and selection of studies

The search term “TITLE-ABS-KEY (vision OR visual OR colour OR colour OR shape OR typeface AND "taste perception" OR "flavor perception" OR "flavour perception")” was used in SCOPUS on March 23, 2023. A total of 531 articles was obtained. Note that the search focused on recent articles, that is, those published after 2010, considering the *Food Quality and Preference* journal guidelines (i.e., “re-review in the light of recent progress in the underlying sciences”) and the already existing relevant papers reviewing previous research on, for example, food colour (e.g., Shankar et al. 2009; Spence, 2015c; Spence et al., 2010). The focus is specifically, on peer-reviewed empirical journal articles that were written in English (and not on reviews, books, book chapter, or conference papers regardless of the language in which they were written). A manual search of the reference lists of relevant review papers (e.g., Spence, 2015a, 2018; Spence et al., 2010; Spence, Wan, et al., 2015) was also conducted to find any eligible studies that may have been missed.

A total of 571 articles was identified. From the title and abstract, those articles that did not examine taste/flavour perception were excluded. In other words, we did not include those articles examining the role of visual cues on expected tastes and/or on food intake if they did not also investigate taste/flavour perception. The focus is specifically on research that studies the influence of colour and/or shapes on taste/flavour perception (i.e., not only on taste/flavour expectations). Research concerning food image and/or tableware (e.g., glass itself, food image placed in a package) was not included because it did not manipulate colours (e.g., hue, lightness) and/or shapes (e.g., curvature). Papers concerning taste/flavour thresholds were not included (Liang et al., 2013; Maga, 1974; Pich et al., 2020).The reason for this exclusion was because effects of visual cues on taste/flavour thresholds may differ from those effects on taste/flavour intensity, when the taste or flavour is already perceivable, as in everyday foods and beverages. We also excluded papers related to taste/flavour discrimination/identification (e.g., Ammann et al., 2020; Levitan et al., 2008; Wang & Spence, 2019; Wieneke et al., 2018; Zampini et al., 2007), given Spence et al.’s (2010) previous review suggesting the differences in the robustness of findings between research on taste/flavour intensity and taste/flavour identification/discrimination. Specifically, the empirical evidence of taste/flavour intensity appears to be more ambiguous than that of taste/flavour identification/discrimination (Spence et al., 2010). Given that the aim of our review was to critically evaluate the literature, we focused on research concerning the intensity of taste/flavour. Thus, when “taste/flavour perception” is referred to in this review~~,~~ it indicates “taste/flavour intensity” (not taste/flavour identification). After applying the aforementioned criteria, a total of 52 papers were included in the review (see Appendix Table A in Supplementary Material for the details). Note that relevant literature published after the search process had been conducted (e.g., Ogata et al., 2023) is not included. A flow diagram that aligns with the PRISMA guidelines (Moher et al., 2009) is shown in Figure 1.

Identification of studies via databases and registers

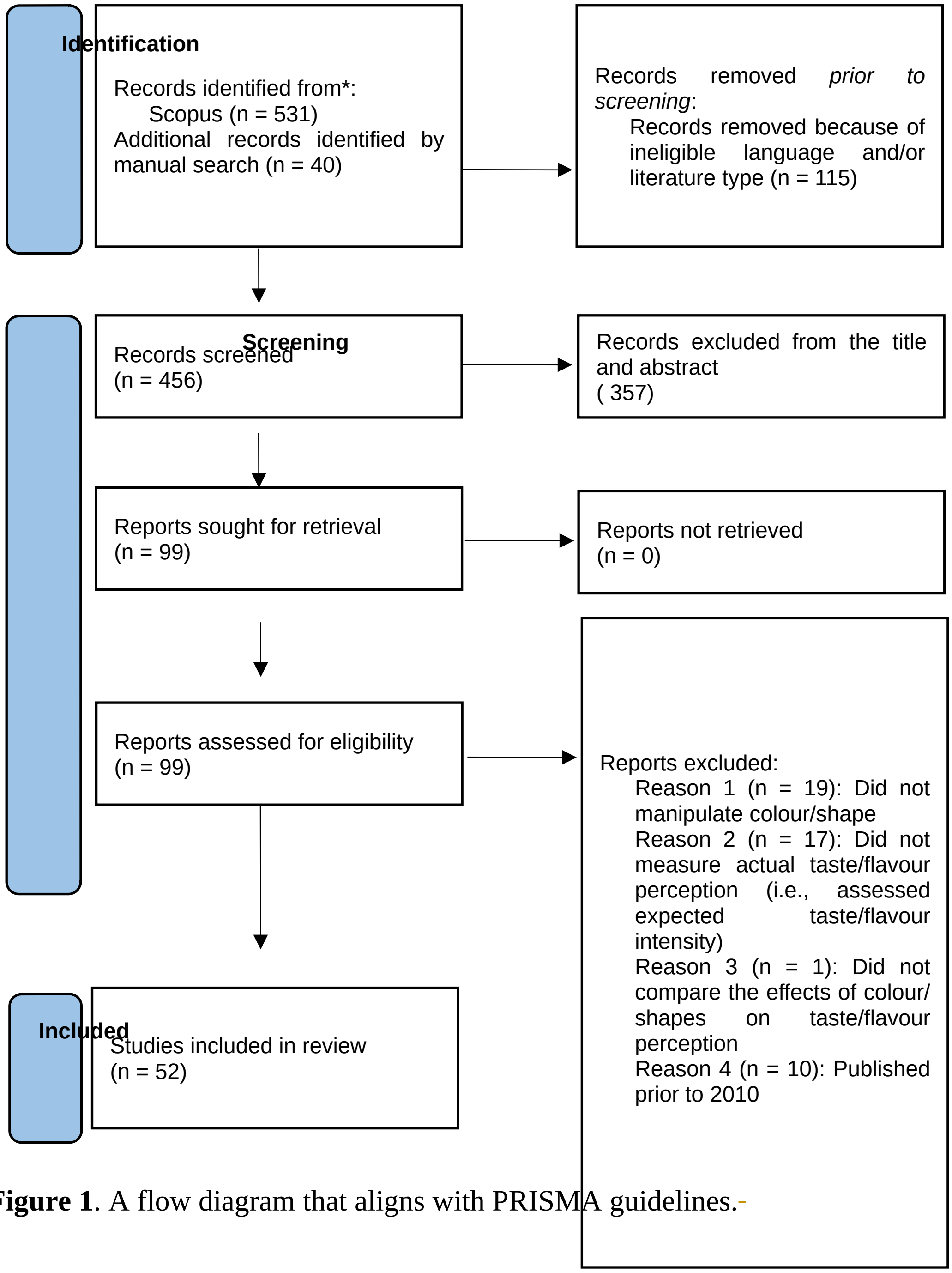

Figure 1. A flow diagram that aligns with PRISMA guidelines.

RESULTS

<u>General characteristics of studies</u>

The majority of the studies (n = 43) manipulated colour, while 16 manipulated shape. ~~Note that a~~A few studies incorporated both manipulations (e.g., intrinsic colours and extrinsic shapes). Amongst those studies that manipulated colour, 30 used extrinsic-colours (e.g., cup colours, ambient; e.g., Harrar et al., 2011; Piqueras-Fiszman et al., 2012; Spence et al., 2014; Wang et al., 2020) while 16 focused on intrinsic-colours, including virtual food colours (e.g., Garber et al., 2016; Harrar & Spence, 2013; Hidaka & Shimoda, 2014; Wang et al., 2022). The majority of studies of product-intrinsic colour used liquids as stimuli, presumably because it is simply much easier to manipulate the colour of liquids. Among the studies that have manipulated shapes, 13 investigated the impact of extrinsic-shapes (e.g., Becker et al., 2011; Otterbring et al., 2022; Sousa et al., 2020a; Stewart & Goss, 2013) while four manipulated intrinsic-shapes (e.g., food shapes) (e.g., Fairhurst et al., 2015; Iuri et al., 2021; Wang et al., 2017). It is also important to consider the combinations of food-intrinsic and -extrinsic cues (e.g., food colour and packaging colour), given that food colour is often seen against extrinsic packaging colour. Three studies manipulated both ~~food-intrinsic and -extrinsic~~ cues simultaneously.

Following the description of the outputs of the search presented above, the findings were grouped in terms of food-intrinsic and food-extrinsic factors. First, the results of studies that manipulating either intrinsic or extrinsic colour are described separately. Next, the results of those studies that manipulating either intrinsic or extrinsic shapes are described separately. Then, the results of studies manipulating more than two sensory cues at once are presented. Meta-analyses were not conducted because the results of many studies did not include statistical details relevant to non-significant results.

Results of studies manipulating intrinsic colour

Several of the studies included (n = 5) documented significant influences of product intrinsic colours on multisensory flavour perception in a manner that would appear to be entirely consistent with the expectations based on the published literature on colour-taste correspondences (Blackmore et al., 2021; Hidaka & Shimoda, 2014; Pellegrino & Luckett, 2019; Suzuki et al., 2017; Wang et al., 2022). Pink (vs. green) drink colours of distilled water with sucrose enhanced sweetness perception (or increase in the perceived intensity; Hidaka & Shimoda, 2014). Yellow coloured potage soup enhanced self-reported warmth and whole-body temperature compared with white or blue coloured soup (Suzuki et al., 2017; see also Guéguen & Jacob, 2014). Blue (vs. green, white) coloured mint-flavoured confectionary increased cooling sensation when the confectionary had no odour (Pellegrino & Luckett, 2019). Dark (vs. light) coloured beer enhanced bitter perception while light (vs. dark) coloured beer increased the perception of refreshment (Blackmore et al., 2021). Saturated (vs. less saturated) red colour enhanced the perception of spiciness of hot sauces specifically when the colour is highly visible (i.e., hot sauce placed directly on the flat bread; Wang et al., 2022).

A number of studies (n = 5) also found significant effects of intrinsic colours on flavour perception, though the results seem somewhat mixed and/or limited (Kpossa & Lick, 2020; Sakai, 2020; Shermer & Levitan, 2014; Sugrue & Dando, 2018; Ueda et al., 2020). For example, one study investigated the effects of the colour of cider (red, green, natural yellow; between-participant) on flavour perception. Red and undyed yellow (vs. green) cider significantly increased the perceived temperature of the drink and red cider also enhanced the perception of body/mouthfeel (Sugrue & Dando, 2018). Note that the colour of the cider did not significantly alter other ratings (e.g., sweetness, sourness, fruitiness, apple flavour, bitterness, or refreshingness; Sugrue & Dando, 2018). One study demonstrated that the crossmodal effects of food colour of macarons were limited to creaminess but did not impact sweetness, crunchiness, or greasiness (Kpossa & Lick, 2020).

Two other studies revealed the conditions under which intrinsic colour influences flavour perception (Harrar & Spence, 2013; Wang et al., 2020). Moreover, intense (vs. less intense) red colour of salsas enhanced spiciness perception only when the piquancy was the higher of the two chosen (Shermer & Levitan, 2014). Additionally, Wang and colleagues have shown that the effects of virtual colour of a coffee beverage on multisensory flavour perception were moderated by the level of sweetness of the drink (Wang et al., 2020). Light brown (vs. dark brown) colour increased creaminess rating when only when the level of sweetness was lower (Wang et al., 2020). No significant effects on sweetness ratings were observed at any of the sweetness levels tested.

Four studies failed~~ound~~ ~~n~~to ~~evidence for~~support the ~~idea~~ claim that intrinsic colours influence flavour perception. For example, no evidence that reddish or lighter food colour enhanced the perception of sweetness was found (Carvalho et al., 2017; Huang et al., 2019; Reinoso-Carvalho et al., 2019; Shermer & Levitan, 2014). The effects of beer colour (dark, pale; within-participant manipulation) did not significantly influence the perception of bitterness, sweetness, sourness, strength, and body (Carvalho et al., 2017).

The studies reviewed in the text provide empirical evidence supporting the idea that intrinsic colours have significant effects on flavour perceptions, in line with the literature on colour-taste correspondences. Specifically, pink hues would appear to enhance sweetness perception, yellow tones evoke the warm sensation of cider, and blue shades notably increased the cooling intensity of the odourless confectionary. In contrast, the effects of product-intrinsic colours on flavour perception display a degree of inconsistency with certain studies indicating significant effects while others yielded non-significant results. Moreover, the influence of colour on taste/flavour perception (i.e., taste/flavour intensity) appears to be contingent on specific contextual factors, encompassing the food category, taste intensity levels, and the presence of particular sensory cues, thereby highlighting the complexity of the relationship between colours and flavour perception. For example, one study revealed that the addition of colour enhanced flavour perception when the flavour was intense (Shermer & Levitan, 2014), while another study showed the opposite: namely, colour increased flavour perception when the level of flavour was low (Wang et al., 2020).

Results of studies manipulating extrinsic colour

Five studies (n = 5) reported significant influences of extrinsic colours on flavour perceptions (Piqueras-Fiszman et al., 2012; Spence et al., 2014; Stewart & Goss, 2013; Tu et al., 2016; van der Heijden et al., 2021). White (vs. black) plate enhanced the perceived sweetness of strawberry mousse (Piqueras-Fiszman et al., 2012) and cheesecake (Stewart & Goss, 2013). Red (vs. white) plate colour increased the perceived spiciness of spicy bean curd (Tu et al., 2016). Other research also manipulated ambient colour of lightning and show that the overall taste intensity of the dish (comprising goat cheese, potato starch, and other ingredients) was increased when the light was bright (vs. dim) (van der Heijden et al., 2021).

A further 13 studies found mixed or limited evidence of the influence of extrinsic colour on flavour perception (Bschaden et al., 2020; Carvalho & Spence, 2019, 2021; Chen et al., 2020; Harrar et al., 2011; Harrar & Spence, 2013; Mielby et al., 2018; Piqueras-Fiszman & Spence, 2012; Risso et al., 2015; Sakarya & Taylan, 2021; Sugrue & Dando, 2018; Tijssen et al., 2017; Van Doorn et al., 2014). Virtual environments containing reddish and round elements increased sweetness perception of grenadine syrup diluted with water compared with those with black and angular cues, while the virtual environments did not significantly alter the perception of bitterness (Chen et al., 2020). The results show that bright (vs. dim) ambient illumination increased salty perception of tomato soup in Study 1. However, no evidence was found for other tastes (sourness, sweetness) in the same study, nor in all taste perception measures (saltiness, sourness, sweetness) investigated in Study 2 (Bschaden et al., 2020). Here it is relevant to note that different lighting manipulation (35 lx vs. 300 lx in Study 1; 145 lx vs. 415 lx in Study 2) might help to explain these seemingly-inconsistent findings (Bschaden et al., 2020). Carvalho and Spence also provided mixed evidence on the effects of cup colour on flavour perception of espresso coffee (Carvalho & Spence, 2019). In the context of Brazilian coffee (which has high sweetness; low acidity), pink (vs. other colours) enhanced the perception of sweetness and green (vs. yellow, pink, white) decreased the perceived acidity. As for Kenyan coffee (which has low-to-medium sweetness; high acidity), yellow or green (vs. pink) enhanced the perception of sweetness while pink (vs. green) increased the perceived acidity, which goes against colour correspondences research whereby green is associated with acidity.

Several other studies (n = 8) found no evidence that product-extrinsic colours influence flavour perception (Becker et al., 2011; Kpossa & Lick, 2020; Michel et al., 2015; Piqueras-Fiszman et al., 2013; Sousa et al., 2020a; Wang, Mielby, Thybo, et al., 2019; Wu et al., 2022; Zellner et al., 2018). The colour of the wrapper of spun sugar candies (red, green, orange, purple/pink; manipulated between-participants) failed to significantly affect either sweetness or flavour intensity (Zellner et al., 2018). Colour (pink, green; manipulated between-participants) of coffee packaging labels did not significantly influence post-taste ratings (sweetness, acidity) of coffee (Sousa et al., 2020a). Moreover, ambient colour in virtual environments did not significantly affect any taste ratings of black tea (sweetness, sourness, saltiness, bitterness; Wu et al., 2022). These studies point to the need to consider the source of the colour in studies where colour is a product-extrinsic cue, as a possible factor influencing taste evaluations. There appears to be a difference between colours as diagnostic cues and colours as irrelevant non-diagnostic cues (e.g., in the case of randomly coloured sweetie wrappers).

Several studies (n = 4) revealed some of the possible conditions where the extrinsic colours influenced flavour perception (Annette & Stafford, 2023; Cornelio et al., 2022; Hansen, 2019; Sugimori & Kawasaki, 2022). Blue or red (vs. white) bowls increased the perception of saltiness associated with food snacks (crisps), only for “picky-eaters”, highlighting possible individual differences (Annette & Stafford, 2023). What is more, wrapping paper colour or cup colours influenced flavour perception that accord with crossmodal correspondences when chocolate is bitter or participants are not super-tasters[1] (Sugimori & Kawasaki, 2022). Ambient blue (vs. neutral) in virtual environments increased the sweetness rating of jelly samples only when the tasting samples were neutral (Cornelio et al., 2022). Moreover, one study found that cup colour

[1][1] An individual’s taster status can be measured by PROP (6-n-propylthiouracil). Super-tasters perceive intense bitterness from PROP (Bartoshuk, 2000).

could alter flavour perception of standard-flavour energy drink only when high-level construal (i.e., abstract mental representations) is primed (Hansen, 2019).

The body of research that has been published since 2011 on the influence of extrinsic colours on flavour perception reveals a diverse and nuanced ~~landscape~~ set of findings. While some studies demonstrate significant effects of extrinsic colours on flavour perception, a larger number of studies yield mixed, limited, or null results. This complex range of findings may be attributed to the identification of specific boundary conditions, such as individual differences like picky-eaters and taster status (i.e., super-tasters vs non-tasters). Moreover, the effects of extrinsic colours on flavour perception seem to be contingent on contextual factors, as evidenced by the impact of colour on flavour perception being modulated by the type of food or drink being evaluated, illumination conditions, and high-level construal. Additionally, many studies manipulated colour hue, but not colour saturation/lightness. ~~We~~ It would seem logical to suggest that ~~would expect~~changes to colour hue ~~t~~would primarily affect taste/flavour identification ~~and~~while saturation/lightness manipulations might be expected to influence taste/flavour intensity ratings. This could be another potential reason for the mixed results observed to date. Overall, these findings underscore the multifaceted nature of the relationship between extrinsic colours and flavour perception.

Results of studies manipulating intrinsic-shapes

Four studies (n = 4) investigated the effects of intrinsic shapes on flavour perception (Cornelio et al., 2022; Fairhurst et al., 2015; Iuri et al., 2021; Wang et al., 2017). Three studies (n = 3) found mixed or limited evidence for the influence of intrinsic shapes on flavour perceptions (Cornelio et al., 2022; Fairhurst et al., 2015; Iuri et al., 2021). Chocolate shapes (round, angular; between-participant factor) influenced only creaminess perception, but not sweetness, bitterness, or liking ratings (Iuri et al., 2021). Food shapes (round, angular) influenced sweet perception only when the sample was a sweet jelly (Cornelio et al., 2022). Specifically, round (vs. angular) samples were found to increase the perceived sweetness of the samples (Cornelio et al., 2022).

Moreover, one study found that the intrinsic and extrinsic shapes (i.e., plate shapes and dish shapes) interactively influenced the perception of sweetness of a complex dish (e.g., beetroot, goat curd, micro chard, etc.), but not of sourness (Fairhurst et al., 2015). The round shaped foods in a round plate were rated as sweeter than the angular food shapes on an angular plate. One study found no evidence that food shapes affected flavour perception of chocolate (Wang et al., 2017). Chocolate shapes (round, angular;

within-participant factor) did not show a significant influence on post-taste ratings (sweetness, bitterness, creaminess, liking; Wang et al., 2017).

Based on the studies reviewed in this section, it would appear that there is mixed evidence for the effects of intrinsic shapes on taste and flavor perception. Significant influences of intrinsic shapes on flavour perception were not observed consistently. Most studies rather show the mixed, limited, and/or null findings, though these results seem not to be surprising given that shapes appear not to be more strongly associated with taste/flavour than colour.

Results of studies manipulating extrinsic-shapes

Amongst the 18 studies dealing with extrinsic-shapes, some (n = 3) revealed significant influences on multisensory flavour perception (Carvalho & Spence, 2018; Chen et al., 2020; Velasco et al., 2018). Round (vs. angular) typefaces increased sweetness perception, while angular (vs. round) typefaces enhanced the sourness perception of jellybeans (Velasco et al., 2018). Shapes of coffee cups (tulip, open, split; between-participant factor) significantly affected flavor perception of coffee (Carvalho & Spence, 2018). Split (vs. tulip, open) increased both sweetness and acidity ratings (Carvalho & Spence, 2018). Note that the findings obtained by Carvalho and Spence

(2018) might not be due to the physical shape of the cup itself but rather to other factors (e.g., the shape of the cup openings).

There have been mixed or limited evidence (n = 4) of the influence of extrinsic shapes on flavour perceptions (Carvalho & Spence, 2018; Machiels, 2018; Mirabito et al., 2017; Sousa et al., 2020b). Beer glasses with curved sides increased fruitiness and intensity ratings but not other ratings (aroma, bitterness, sweetness) of beer compared with beer grass with straight sides (Mirabito et al., 2017). An angular/straight~~)~~ (vs. round/curved) cup significantly affected only the bitterness, but not other taste/flavour (e.g., sweetness, sourness, smell intensity, taste intensity), perception of a caffeinated soft drink (Machiels, 2018). It is worth mentioning that their cup stimuli not only vary in curvature but also in the vertical dimension/size of the cup potentially confounding the results. No significant effect of drinking cup on flavor perception was found for a strawberry-flavoured buttermilk drink (Machiels, 2018). Angular (vs. round) typefaces of packaging labels enhanced the rated acidity of coffee, while typefaces of packaging labels did not significantly influence ratings of the coffee’s sweetness ~~of coffee~~ (Sousa et al., 2020b).

A subset of studies (n = 4) finds no evidence to support the claim that product extrinsic shapes influence flavour perception (Blackmore et al., 2021; Otterbring et al., 2022; Piqueras-Fiszman et al., 2012; Sousa et al., 2020a). For instance, plate shapes (round, angular; within-participant factor) did not significantly influence the taste perception of strawberry mousse (Piqueras-Fiszman et al., 2012). Typefaces (round, angular; between-participant factor) of containers did not significantly affect the perceived taste of ice-cream (Otterbring et al., 2022). Shapes (round, angular; manipulated between-participants) on the design elements of coffee packaging labels did not influence any aspect of flavour perception of the coffee (Sousa et al., 2020a). Label typeface (round, angular; within-participant factor) did not significantly influence flavour perception of the beer (Blackmore et al., 2021).

Several studies **(n = 3) failed to obtain a significant main effect of extrinsic shapes on multisensory flavour perception but revealed the conditions under which the extrinsic shapes influenced flavour perception (Becker et al., 2011; Fairhurst et al., 2015; Stewart & Goss, 2013). Angular (vs. round) packaging increased taste intensity of yoghurt** when participants **scored higher in sensitivity to design**[2] (Becker et al., 2011). **According to Becker et al. (2011), higher (lower) score in sensitivity to design indicates a greater degree of being design-minded (indifferent to product design). Round white (vs. angular white) plates increased**

[2] Becker et al. (2013) measured the sensitivity to design by using the Centrality of Visual Product Aesthetics scale (Bloch et al., 2003).

sweetness rating of cheesecake, though no main effects of round vs. angular shapes were observed (Stewart & Goss, 2013).

Based on the comprehensive analysis of 18 studies examining extrinsic shapes and flavour perception, certain studies have established significant influences of extrinsic shapes on flavour perception, with round typefaces notably augmenting sweetness perception, and angular typefaces enhancing the perception of sourness. Nonetheless, the majority of the findings present mixed or limited evidence concerning the impact of extrinsic shapes on flavour perception. Interestingly, specific conditions have been identified in some studies where extrinsic shapes influence multisensory flavour perception, such as higher sensitivity to design score leading to taste intensity enhancement in the presence of angular packaging.

Results of studies manipulating multiple sensory cues

Researchers have occasionally manipulated multiple sensory cues (i.e., two or more sensory cues) within the same experiment, and similar to the unisensory studies, they have revealed mixed evidence of the influences of combined visual cues on flavour evaluation.

Extrinsic vs. intrinsic sense

Some studies (n = 3) show that intrinsic visual cues (food colour and shapes), appear to have more influence on flavor perception than extrinsic cues (Blackmore et al., 2021; Kpossa & Lick, 2020; Wang, Mielby, Thybo, et al., 2019). Blackmore and colleagues manipulated the visual appearance of beer (lighter colour, darker colour) and label typeface (round, angular) among other factors, and found that only the colour of the beer influenced taste evaluations (Blackmore et al., 2021; see also Barnett & Spence, 2016). Specifically, darker (vs. lighter) coloured beer was rated as more bitter, less refreshing, as having more body, and as being less liked. Wang and colleagues manipulated bottle colour (none, pink, yellow), music (none, sweet soundtrack, bitter soundtrack), and aroma concentration (none, medium, high). Although extrinsic colour did not significantly influence flavour perception, intrinsic sensory cues (i.e., aroma) and also music altered the perceived flavour of fruit beverages (Wang, Mielby, Thybo, et al., 2019). Moreover, Kpossa and Lick manipulated both food (macaron) and plate colour, and showed that only food colour significantly influenced the perception of creaminess (Kpossa & Lick, 2020). It should be noted that some studies have shown mixed results (Cornelio et al., 2022; Harrar & Spence, 2013; see also Fairhurst et al., 2015, for the interactive effects of extrinsic and intrinsic shape).

Some studies suggest that extrinsic shape/colour can influence taste and flavour perception. Other studies also have found that intrinsic factors such as aroma and food colour may play a more significant role than extrinsic factors. Taken together, the findings that are somewhat surprising highlight the importance of considering both intrinsic and extrinsic factors in understanding taste and flavour perception. As was the case in the previous sections, some studies have also resulted in complex or mixed findings.

Colour vs. shape

Previous research (n = 3) has manipulated colour and shape and investigated the effects of each cue on flavour perception (Becker et al., 2011; Piqueras-Fiszman et al., 2012; Stewart & Goss, 2013). On the one hand, one study found that colour rather than shape influenced flavor perception (Piqueras-Fiszman et al., 2012). Piqueras-Fiszman manipulated plate colour (Experiment 1) and plate shape (Experiment 2) by using the same food stimuli (strawberry mouse) (Piqueras-Fiszman et al., 2012). In this study, only plate colour affected ratings of taste perception such that white (vs. black) plates increase the ratings of intensity, sweetness, and liking. Given that the food was presented in a striking pyramidal shape, this may help to explain the null findings of plate shape in Piqueras-Fiszman et al.'s (2012) study. The striking shape of the food in the foreground might result in less attention being paid to the shape of the plateware in the background.

On the other hand, one study suggested that shape rather than colour exerts a significant influence over flavour perception of yoghurt only amongst those participants scoring higher in terms of their sensitivity to design (Becker et al., 2011). Note that one study manipulated plate colour (white, black) and plate shapes (round, angular) and observed interaction effects of the two factors (Stewart & Goss, 2013). White round shape (vs. white angular shape) increased sweetness perception and intensity ratings. Other research indicated that no evidence of the role of both colours and shapes on taste/flavour perception of coffee (Sousa et al., 2020a). Taken together, the results of the small number of studies that have examined the relative effects of multiple cues on multisensory flavour perception since 2011 appear to be mixed.

In conclusion, prior research on the influence of multiple sensory cues on flavor perception has yielded mixed evidence. While some studies suggest that intrinsic factors, such as aroma and food colour, may have a significant impact on flavour perception, others have observed effects of extrinsic factors, such as plate colour. Moreover, the relative influence of colour versus shape on flavour perception remains inconclusive, with some studies showing colour to be more influential, while others highlight the significance of shape, and yet others suggesting interactive effects. Overall, these findings underscore the complexity of the interplay between intrinsic and extrinsic visual cues in influencing taste/flavour perception.

GENERAL DISCUSSION

Summary of findings

In the present study, a systematic review of the literature on the crossmodal intrinsic and extrinsic influence of colour and shape on taste/flavour perception was conducted. A total of 52 studies that met the criteria for inclusion were evaluated. Some findings demonstrate significant crossmodal influences of colours/shapes on taste/flavour perceptions consistent with the shape/colour-taste correspondences that have been documented to date (e.g., Blackmore et al., 2021; Hidaka & Shimoda, 2014; Pellegrino & Luckett, 2019; Suzuki et al., 2017; Wang et al., 2022). Meanwhile, even when significant effects were observed, they were not always in agreement with the findings from vision-taste correspondences research. Moreover, some studies show no evidence of colours/shapes significantly influencing flavour perception. Given the mixed findings, it is natural to search for moderators, or the potential boundary conditions, for when/how visual cues influence taste/flavour perception. We will discuss possible accounts for the moderators or the potential boundary conditions.

When/how do crossmodal correspondences lead to crossmodal effects?

When/how do crossmodal correspondences lead to crossmodal effects on flavour perception? In other words, why does some research show significant effects of visual cues on flavour perception (e.g., see Motoki, Marks, & Velasco, submitted) while others do not. Possibly, there are some reasons why several studies show significant effects of extrinsic-visual cues on multisensory flavour perception. Given that inconsistent findings (significant, mixed, limited, and/or null results) have been identified in this review, it seems that several boundary conditions may need to be met in order for significant effects to be obtained.

The salience/attentional capture of visual cues

The salience/attentional capture of visual cues might be a possible moderator of the influence of visual cues on multisensory flavour perception. When the visual cues are salient and/or attention-capturing, the cues may be more likely to influence taste/flavour perception. Salience indicates the degree of some pieces of information are more “stand-out” and/or more attention-capturing than others (Greifeneder et al., 2011, p.

111). The salience/attentional capture of visual cues may be due to visual cues themselves, task characteristics, and/or individual dispositions (see Greifeneder et al., 2011). Some of the previous findings might be explained by the degree of salience of the manipulated senses. Moreover, the instruction to attend to extrinsic visual cues (e.g., wine labels coloured in red or green) used in previous research (Sugrue & Dando, 2018) might well have increased the saliency of the extrinsic information, which possibly resulted in the significant results obtained. Shankar et al., (2010b) provided the relevant findings to support the account of the salience of visual cues. Colour cues could not influence flavour perception when the colour cues are far from (and do not appear salient). Consequently, the salience of visual cues might, at least in part, help to explain the inconsistent findings that have been published in the literature.

The salience of visual cues likely varies between studies, even though the "same" colour/shape manipulations can be applied. Basic effects of colour/shape-taste correspondences have usually been obtained from simple stimuli such as colour patches and geometric shapes (Wan, Woods, et al., 2014). However, the manipulation of colours and shapes differ among prior research (see Appendix Table A in the Supplementary Materials). For example, the degree of roundness may vary among studies manipulating round shapes (e.g., Becker et al., 2011; Piqueras-Fiszman et al., 2012). This may lead to different shape perception, and then distinct taste expectations between previous studies. Moreover, prior research used various visual features for crossmodally corresponding stimuli and control stimuli. For example, some research used white (sweet enhancing colour) versus black (control colour) for stimuli (Piqueras-Fiszman et al., 2012) while other research used pink (sweet enhancing colour) versus white (control colour) for stimuli (Harrar & Spence, 2013). Further research also may use an objective measure of visual saliency (e.g., Cornia et al., 2018; Katramados & Breckon, 2011; Shi et al., 2013), and determine to what extent salient visual cues affect taste/flavour perception.

The perceived diagnosticity of visual cues regarding the signalling of taste/flavour

The perceived diagnosticity regarding the signalling of taste/flavour appears to be a potential moderator of the effects of visual cues on taste/flavour perception. Visual cues would also be more likely to influence taste/flavour perception when the feelings are perceived to be diagnostic (or informative) in forming tasting evaluations. For example, while pink and round shapes are associated with sweet tastes, the~~ pink and round shapes~~y appear not to be diagnostic for the taste/flavor perception of savoury foods that are not predominantly sweet tasting. It also seems that the colour cues of some food products/drinks are more diagnostic/informative than others. For instance, commodity coffee is nearly always black, and any subtle variations in the visual appearance of coffee do not appear to be very informative about the taste profile of coffee (but see Yeager et al., 2022 for the effects of roast level/temperature on the colour of coffee). In contrast, wine offers many gradations of colour, and the intrinsic colours of wine are meaningful in terms of setting expectations and forming tasting evaluations (see Wang & Spence, 2019). Moreover, the number of colours associated with a particular taste/flavour and/or the number of tastes/flavours that are associated with a given colour might partly determine the extent to which colour can be considered diagnostic[3]. Saltiness is often associated with white (e.g., Wan et al., 2014), but as Maga (1974) noted, salty foods exist in a wide range of different colours (e.g., yellow potato chips, brown pretzels, canned green beans, white salt;~~ Maga, 1974~~). Thus, ~~the ~~colour ~~associated with saltiness (i.e., white) ~~might not be a highly diagnostic colour for saltiness in foods.

The information derived from intrinsic visual cues is likely to be perceived to be more diagnostic (or informative) regarding the signalling of taste/flavour than extrinsic visual cues (e.g., such as ambient colour or packaging colour). The intrinsic visual cues may carry information on the physical properties of foodstuffs, and they may be

[3] It should be noted that the variety of semantic associations linked with colours and/or taste/flavour might also be related to the perceived diagnosticity regarding the signalling of taste/flavour.

informative about the taste/flavour profile. For instance, the colour lightness of beer may be indicative of its expect~~ation of~~ed bitterness and body (Blackmore et al., 2021). Blackmore et al.'s study also shows that only beer colour, but not label typeface, influenced bitterness and body perceptions of beer.

The level of flavour expertise might be also susceptible to the influence of visual cues on taste/flavour perception. The flavour experts (e.g., wine sommelier) have a greater knowledge and/or experiences of intrinsic-colour and taste/flavour associations (but see Shankar et al., 2010d; Wang & Spence, 2019). Some negative findings reported here might be partially explained by the participants discounting the visual cues as not being diagnostic with regard to taste/flavour.

The degree of discrepancy between the expected and the actual taste/flavour experiences also can be understood in terms of the perceived diagnosticity of visual cues. Previous research, according to the assimilation/disconfirmation model, has demonstrated that colours do not significantly affect taste/flavour perception when there is a discrepancy between the colour-based taste/flavour expectations and the actual taste/flavour experience (e.g., Shankar et al., 2010c; Yeomans et al., 2008). For example, there is a discrepancy between the expectations of sweetness from the pinkish ice-cream and the actual experience of savoury~~lty~~ frozen ~~-~~salmon/crab bisqué ~~frozen~~

(Yeomans et al., 2008). In this case, the sweetness expectation from the pinkish colour is not diagnostic for tasting salty foods, and the predicted crossmodal effects (i.e., pink colour increases sweetness) do not likely to occur.

The strength of association between visual cues and taste/flavour

The strength of the association between a sensory cue and flavour attributes might also be a crucial factor influencing the effects of colour and shape on taste/flavour perception. Previous research has shown that the magnitude of facilitation or interference of a colour cue on word processing can be influenced by the strength of the association between a colour and a word (Berthet et al., 2011; Lewis et al., 2013; Tanaka & Presnell, 1999), and this may extend to the case of vision–flavour correspondences. Food products with flavours that have a stronger typicality of colour (e.g., strawberries and red) may be more influenced by colour cues compared to those flavours having weaker colour associations (or typicality), like salty-tasting products (Maga, 197~~3~~4). The strength of the colour identity may depend on various factors, including the product category (Berthet et al., 2011), which could lead to different effects of colour and shape on flavour perception in different food contexts. Indeed, Velasco and colleagues (2015) highlighted that the difference between congruent and incongruent colour-flavour words was larger in the stronger association condition relative to the weaker association condition (Velasco et al., 2015). Notably, Maga (1974) also suggested almost half a century ago that the strength of association between colours and tastes is dependent on taste types. Specifically, the colour-salty associations seem not to be strong, because salty foods (e.g., potato chips, pretzels, green beans) come in a wide range of different colours.

Some of the negative findings reported ~~here~~ in the literature reviewed here might partially be explained by the limited strength or context dependency of the association between visual cues and taste/flavour. Although one might say that the strength of association differs from a crossmodal effect, some evidence suggests that the account of the strength of association between visual cues and taste/flavour may underlie the negative findings. There appear to be individual differences in the degree of matching between shape/colour and tastes (Chen et al., 2021; Hamamoto et al., 2020; Shankar et al., 2010b). Visual cues appear to influence flavour perception more for those who have beliefs~~,~~ that are general or product-specific, of matching between colour and tastes~~.~~ (Shankar et al., 2010a). For example, pink colours would induce sweet expectations for those who consider that pink colours are strongly matched with sweetness. ~~The~~An infividual's taster status ~~(e.g., sweet liker)~~ might underlie the individual differences in the degree of matching between shape/colour and tastes (Bartoshuk, 2000). Given the valence matching of stimuli (e.g., sweetness and round shapes are both positively valence and then well matched; see Motoki & Velasco, 2021), sweet dislikers match sweetness with round shapes less, which might explain in part the diverse results that have been published to date. Furthermore, the strength of associations of colour with taste/flavours differ between different cultural groups (Shankar et al., 2010b). For instance, brown coloured drink was associated with “grape” flavour in British participants, while it was associated with “cola” flavour amongst Taiwanese participants (Shankar et al., 2010b; see also Velasco et al., 2016).

The evaluative malleability of food judgments

Visual cues would be more likely to be transferred to tasting experiences, when the foods are evaluatively malleable (the latter term referring to the degree to which food judgments are changeable or open to extraneous influences). The evaluative malleability of food judgments might be possible moderators of the visual cues on flavour perception. The taste/flavour perception of food appear to be evaluatively malleable when the foods and/or their taste/flavour are ambiguous, novel, and/or unstructured (see Greifeneder et al., 2011). This suggests that taste/flavour perception of certain foods appear more open to extraneous influences by visual cues than those about other foods. For instance, taste/flavour perception of foods with complex taste/flavour (e.g., wine, craft beer) may be more influenced by visual cues than that of foods with simple taste/flavour (e.g., water with much sugar).

~~Some of the significant and non-significant findings might be attributable to the degree of the evaluative malleability of food judgments.~~ A study by Nasri et al. (2011)~~One study~~ ~~shows~~ demonstrated that odour-induced saltiness enhancement depends on the level of salt~~ (Nasri et al., 2011)~~. Specifically, when the salt level was high, the salt-related odours failed to enhance the perception of saltiness (Nasri et al., 2011). Such a result might either be taken to~~This~~ suggest~~s~~ that when the intensity of taste/flavour is too high, extrinsic factors like visual cues ~~appear not to~~do not affect taste perception, or else that colour intensity/saturation will only modify taste intensity ratings when it is different from the actual taste of the food/drink[‡]. Moreover, other research also demonstrates that extrinsic factors, such as verbal labels, can influence the perception of sweetness when the drink was weaker (i.e., less sweet, 50% orange juice & 50% water; Woods et al., 2011). Extrinsic colours also can modulate taste/flavour perception when the taste intensity is not high (Harrar et al., 2011). Blue (vs. white) coloured bowl increased salty perception of less salty popcorn (i.e., sweet popcorn;

Harrar et al., 2011). Regarding the influence of shapes on flavour perception, significant findings were observed when the flavour of food stimuli (i.e., jellybeans) appeared to be complex (i.e., the flavour ~~is a mix of~~combines both sweet and sour; see Velasco et al., 2018) and thus malleable. The evaluative malleability might be understood in terms of the discrepancy between expectations and the actual experienced taste/flavor intensity. When the foods are evaluatively malleable, the difference between taste/flavor expectations based on visual cues and the actual experienced taste/flavor intensity is not large. In such cases, visual cues are more likely to influence taste/flavor perception.

Recommendations for future research

Given the heterogeneity of results and different research practices, we critically discuss the reviewed studies, highlight the pitfalls in the literature that has been published in recent years, and make recommendations for robust research practices moving forward.

First, it is important to consider the availability of study materials and procedures, or alternatively, to provide detailed information about them. Researchers may choose to store study materials (e.g., images of stimuli) on the Open Science Framework (OSF: https://osf.io) and/or in the online supplemental materials sections that some journals now offer. Detailed information concerning visual cues and taste, flavour, and food stimuli can also be provided. Examples include the actual size of the visual cues, the colour parameters of the stimuli, the degree of roundness/angularity, the degree of subjective matching between visual cues and taste/flavour (e.g., how pink colour goes well with sweetness) within the tested sample, and the characteristics of the food stimuli (e.g., dominant taste/ flavour, subjective complexity of taste/flavour). Making sure to provide all pertinent information concerning the presence or absence of specific instructions that might influence the saliency/relevance of visual cues could turn out to be helpful in understanding when and why some studies yield significant results whereas others do not.

Second~~l~~y, ~~it is recommended that~~ basic statistics for all results should ideally be made available. Many previous studies ~~do~~ fail ~~no~~to provide detailed statistical information, especially for non-significant findings. However, ~~Even for non-significant findings,~~ providing a summary of all statistical ~~information~~results, regardless of their significance (e.g., mean, SD, t-value, p-value) can be stored on OSF and/or in online supplementary materials. This kind of information is also beneficial for future meta-analyses. It is also possible for researchers to add the raw data in OSF and/or online supplementary materials. If they do so, readers interested in the details can access and analyse the data.

Third~~ly~~, regarding the effects of colour on taste/flavour perception, most studies manipulated colour hue rather than colour saturation/intensity. It is worth noting ~~could be~~ that colour saturation/intensity may exert a more natural affinity with/influence over taste/flavour intensity than colour hue. More research is needed to consider the role of colour saturation/intensity and colour hue-saturation/intensity interactions on taste/flavour perception.

An additional challenge in this context is that the association between colour and taste/flavor can be expected to vary across cultures. For example, different-coloured drinks are linked to distinct flavors in different cultures (Shankar et al., 2010b). British participants tend to associate brown-coloured drinks with a 'grape' flavor, while Taiwanese participants associate it with a 'cola' flavor (Shankar et al., 2010b; also see Velasco et al., 2016). These potential cultural differences complicate the interpretation of studies conducted in diverse cultural settings. To gain a nuanced understanding of the effects of colours on taste/flavour perception, multi-country studies encompassing a diverse and representative range of cultures would be needed (see Velasco et al., 2016).

Finally, most of studies reviewed here were not pre-registered, and do not include power calculations to determine appropriate sample size (which has become increasingly standard practice in recent years). Note that some studies were published prior to pre-registration becoming popular and it worth balancing exploratory and confirmatory research through pre-registration. Considering the lack of such practices, the credibility and reproducibility of these findings are not clear. Independent teams should consider running high-powered pre-registered replication studies, though these attempts are difficult due to the laboratory experiments required for this kind of study. . For example, one well-cited study (Becker et al., 2011), which demonstrated individual differences in design sensitivity as a moderating factor of visual cues on taste/flavor perception, seems to have never been followed up and evaluated in subsequent research.

Limitations and future directions

Meta-analyses were not conducted because the results of many of the studies reviewed here did not include statistical details specifically when the results were non-significant. Conducting systematic review would have an easier job if all the statistics, including all null results, had been reported. It should be noted that quantitative meta-analysis is by no means perfect (Sharpe, 1997; Simonsohn et al., 2022). Quantitative meta-analysis is potentially subject to the problem of publication bias, inclusion of poor-quality studies, and the mixing of studies that are dissimilar in key relevant dimensions, which might result in misleading generalizations (Sharpe, 1997; Simonsohn et al., 2022). Regarding the mixing of dissimilar studies, prior studies in even the same category (e.g., “intrinsic colour”) have often used different colours, different food stimuli, and different response measures (see Appendix Table A in Supplementary Material). Although which differences (e.g., colours, food stimuli, response measures, cultural groups) are relevant remain elusive, given the heterogeneity, the quantitative meta-analysis seems not necessarily to be preferrable in our review.

Systematic research is needed to assess whether there is an interaction between extrinsic objects (e.g., cup, napkins, wrapping paper, packaging) and colour on taste and flavor perception. One potential approach to this research would be to design experiments that systematically manipulate the colour of extrinsic food and beverage objects and then measure the impact of those manipulations on flavor perception (see Zampini et al. 2007, 2008). For example, researchers could examine whether the colour of a cup vs. wrapping paper vs. packaging affects how people perceive the taste of a particular food or whether the colour of a plate or napkin influences how people perceive the flavor of a particular food (see Zellner et al., 2018). One might hypothesize that the level of diagnosticity of the colour of the object might represent the strongest effect, assuming that there is room in the food object's sensory characteristics as well as the individual's perceptual characteristics.

It is important to stress that the present review does not address some of the marked differences in statistical power and/or methodologies amongst different studies. Statistical power is the probability of avoiding a Type II error (Baguley, 2004). Typically, the larger sample size is, the higher the statistical power is. However, our selected studies vary in sample size (see Appendix Table A in Supplementary Material) and thus likely also statistical power. The heterogeneity of statistical power across studies might be expected to impede accurate results for us to some extent. Moreover, our review has not taken into account the differences in experimental design in prior studies. One study reported differential findings dependent on the experimental design (Biggs et al., 2016). The within-participant design, but not the between-participant design, can find the reliable effects of sensation transference from the haptics to taste/flavour (Biggs et al., 2016). Typically, the differences between visual cues are more “salient” in the within-participant than in the between-participant design (see Meyvis, & Van Osselaer, 2018). It is because participants are likely to rate taste/flavour perception based on the differences of visual cues (e.g., round versus angular). Note that the within-participant design has a more risk of being the experimenter demand effect than the between-participant design. Hence, the experimental design used in previous studies might partially explain some of the inconsistent findings that have been highlighted by this systematic review.

One of other limitations involve the studies selected for this review. This review includes only those studies published after 2011. In other words, our review does not include works that published before 2010 where much work on colour affecting taste/flavour was conducted (e.g., Garber et al., 2000, 2001; Spence et al., 2010; Zampini et al., 2007, 2008). Prior to 2010, many studies had already tested the effects of intrinsic colours on flavour identifications (Spence et al., 2010, for a review). There is presumably a possibility that those studies reviewed here and published over the last decade, attempted to address residual questions in the literature that had not been satisfactorily addressed in the preceding 70 years of research on the topic. Furthermore, the search terms used to select studies might influence the number of literature identified.

Looking to the future, Bayesian causal inference (e.g., Maximum Likelihood Estimation) ~~would~~ may provide a framework ~~have~~for ~~any role in~~ helping to model~~better~~/ understand the complexities of crossmodal effects on taste/flavour perception. The basic idea here is that the brain assigns greater weight to those sensory cues that are more reliable when forming the overall multisensory perception, as compared to less reliable cues (see Spence, & Levitan, 2022). ~~It has been suggested that~~ ~~m~~Multisensory flavour perception involving olfactory and gustatory cues might be well formalized in terms of the Bayesian causal inference (Spence, 2016). Recent research has shown that rats adaptively weight taste and odour information to make preferential judgement (Maier & Elliott, 2020). However, to the best of our knowledge, no research has taken the computational approach to modelling the effects of visual cues on taste/flavour perception.

Conclusions

In conclusion, this systematic review critically evaluated the relevant literature published after 2011 that examined effects of colours and shapes on taste/flavour perception. Some findings demonstrate that significant influences of colours/shapes on taste/flavour perceptions consistent with the shape/colour-taste correspondence. Meanwhile, the mixed, limited, or null evidence of the effects of both intrinsic and extrinsic cues are also found. Several factors may moderate the effects of visual cues on flavour perception, including the salience of visual cues, the perceived diagnosticity of visual cues regarding the signalling of taste/flavour, the strength of association between visual cues and taste/flavour, as well as the relevance and evaluative malleability of food judgments.

Footnotes

1. The findings reported by Nasri et al. (2011) might not be explained by the account of evaluative malleability. If the food itself already possesses a matching salt level with salt-related odour, the salty smell alone could not contribute further to the salty perception. Thus, the precise matching of expectations of extrinsic factors and the intensity of taste/flavor seems to be crucial.

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Supplementary material

Appendix Table A. Selected studies included in the review.

Author(s) and year of publication	Number of participants	Food intrinsic or extrinsic	Manipulations of senses	Food stimuli	Measures of taste/flavour perception	Null results	Significant findings	Supporting sensory transfer from vision to tastes/flavour
Becker et al., 2011	151	Extrinsic shape Extrinsic colour	Packaging shape (angular, rounded) × packaging colour (low saturation, high saturation) × sensitivity to design (low, high) between-participants factorial design.	Lemon yoghurt	Taste intensity	Taste intensity for packaging colour	Taste intensity (angular > round) when participants are higher in sensitivity to design score	Partial - Only amongst those participants who were more sensitive to design
Harrar et al., 2011	60	Extrinsic colour	Plastic bowl colour (blue, white, red, green; within-participant),	Popcorn (salty, sweet)	Sweetness, saltiness, liking	Liking	Sweetness (red, blue > white for *salty* popcorn)	Partial - Only when

			flavours (salty, sweet; within-participant)				Saltiness (blue > white for *sweet* popcorn)	taste/flavor is sweet or salty
Piqueras-Fiszman et al. 2012	E1: 43 E2: 51	Extrinsic colour Extrinsic shape	E1: Plate colour (white, black; within-participants) E2: Plate shapes (round, angular; within-participants)	Strawberry mousse	Intensity, sweetness, quality, liking	Plate colour: Quality Plate shapes: Intensity, sweetness, quality, liking	Intensity, sweetness, liking (white > black)	Partial - Only when the manipulation is extrinsic colour (i.e., and not for extrinsic shape manipulation)
Piqueras-Fiszman & Spence, 2012	57	Extrinsic colour	Plastic cups of colours (white, dark cream, red, reddish orange; within-participants)	Sweetened or unsweetened chocolate drink	Liking, chocolate flavour, chocolate aroma, sweetness	Chocolate aroma, sweetness	Liking (orange > white) Chocolate flavour (orange > red, white)	Partial - Only flavour rating
Piqueras-Fiszman et al. 2013	253	Extrinsic colour	Plate colours (white, black; between-participant), Three deserts (A, B, C; between-participants)	Three desserts	Flavour intensity, sweetness, liking	Flavour intensity, sweetness, liking	None	No
Harrar & Spence,	E2: 40	Extrinsic colour	E2: Spoon colour (five colours), yoghurt colour (pink, white; within-	Yoghurt	E2: Expensiveness,	E2: Liking	E2: Saltiness (pink > white yoghurt for blue spoon), sweetness (white	Partial - Unexpected

2013		Intrinsic colour	participants)		liking, sweetness, & saltiness		spoon > black spoon), expensiveness (white spoon > black spoon)	directions
Stewart & Goss, 2013	48	Extrinsic colour Extrinsic shape	Plate colour (white, black; between-participants) Plate shapes (round, angular; between-participants)	Cheesecake sample	Sweetness, intensity, quality, & liking	None	Sweetness (white > black; round white > angular white) Intensity (round white > round black, square white) Liking (round white > round black; angular black > angular white) Quality (round white > round black; angular black > angular white)	Yes
Hidaka & Shimoda, 2014	E1: 10	Intrinsic colour	Drink colour (pink, green)	Distilled water with sucrose	Sweetness	None	Sweetness (pink > green)	Yes
Shermer & Levitan, 2014	24	Intrinsic colour	Food color intensity (high, low), piquancy (high, low), viewing condition (sight, blind)	Salsas	Spiciness	None	Spiciness (higher colour intensity > lower color intensity) when the piquancy is high	Partial - Colour intensity influenced the rating of spiciness when the food is higher-level

								phiquancy
Spence et al., 2014	E1: 1,580 E2: 1,309 *8% of the data were excluded due to incomplete ratings	Extrinsic colour	Ambient coluour/music (white lighting, green lighting, red lighting with sweet music, green lighting with sour music)	Wine	fresh/fruity scale, flavour intensity, liking	None	Fresher (green lighting/sour music > other ambiences) Flavour intensity (other ambiences > green lighting/sour music) Liking (red lighting/sweet music > other ambiences)	Yes
Van Doorn, Wuillemin, & Spence 2014	E1: 18 E2: 36	Extrinsic colour	Experiments 1-2: Cup colour (white, blue, transparent; between-participant)	Café latte	Sweetness, aroma, bitterness, intensity	E1: Sweetness, aroma, bitterness E2: Aroma, bitterness, intensity	E1: Intensity (white > transparent) E2: Sweetness (blue > white, transparent)	Partial - Only sweetness rating & results in unexpected direction
Fairhurst et al., 2015	16	Extrinsic shape Intrinsic shape	Plate shape (round, angular; between-participant), dish presentation (round, angular; within-participant)	Three pieces of beetroot served with goat curd, micro chard	Sweetness, sourness	Sourness	Sweetness (round plate/round dish - round plate/angular dish > angular plate/angular dish - angular plate/round dish)	Partial - Only sweetness rating

				and micro watercress and fried shallots				
Michel et al., 2015	121	Extrinsic colour	Plates (square black, round white; between-participant)	Dessert (treacle tart with clotted cream ice cream)	Liking, sweetness, flavour intensity	Sweetness, flavour intensity	Liking (square black plate > round white plate)	No
Risso et al., 2015	27	Extrinsic colour	Colour of plastic cup (white, red, blue; within-participants), Water type (still, slightly carbonated, carbonated; within-participants)	Three types of water (still, slightly carbonated, carbonated)	Freshness, pleasantness, carbonation and lightness	Freshness, pleasantnes s, lightness	Carbonation (blue, red > white)	Partial - Only carbonation rating
Garber et al., 2016	531	Intrinsic colour	Flavour (orange, lemon), drink colour (orange, yellow, clear) full-factorial	Flavoured water	Sweet, "Flavourful, all-natural, inexpensive", "Refreshing, good for me" etc.	"Flavourful, all-natural, inexpensive "	“Refreshing, good for you” (yellow > orange, clear) Sweetness (clear lemon > orange colour/lemon, yellow colour/lemon)	No

Tu et al., 2016	E2: 48	Extrinsic colour	E2: Plate colour (red, white; between-participant factor), spiciness (light, severe; between-participant factor)	Spicy bean curd	Spiciness	No significant interaction of plate colour with spiciness level	Spiciness (red > white)	Yes
Mirabito et al., 2017	53	Extrinsic shape	Glass shape (curved, straight; within-participant)	Beer	Aroma, bitterness, fruitiness, intensity, pleasantness, sweetness	Aroma, bitterness, pleasantness, sweetness	Fruitiness (curved > straight) Intensity (curved > straight)	Partial - Only fruitiness and intensity ratings
Reinoso Carvalho et al., 2017	136	Intrinsic colour	Beer colour (dark, pale; within-participant)	Blond-ale beer produced in-house-	Liking, bitterness, sweetness, sourness, strength, body	Liking, bitterness, sweetness, sourness, strength, body	None	No
Suzuki et al., 2017	12	Intrinsic colour	Soup colour (white, blue, yellow; within-participant)	Potage soup	Warmth (self-reported, whole body, toe)	None	Self-reported warmth (yellow, white > blue) Whole body temperature (yellow, white > blue)	Yes

Toe temperature (yellow > white, blue)

Tijssen et al., 2017	81	Extrinsic colour	Packaging hue (blue, red), brightness (high, low), saturation (high, low)	Dairy drink and sausage	Dairy drink: Creaminess, flavour intensity, sweetness, fruitiness Sausage: Fattiness, flavour intensity, saltiness	Saltiness, Fruitiness	Dairy drink: Sweetness (high saturation > low saturation; Red and high saturation > others), Flavour intensity (blue and low saturation > red and low saturation), Creaminess (red > blue; high bright > low bright; red & high brightness > others; others > blue & high saturation) Sausage: Fattiness (low bright > high bright), Flavour intensity (low bright > high bright; low bright & low saturation > others)	Partial

Wang et al. 2017	102	Intrinsic shape	Chocolate shapes (round, angular; within-participants factor)	Chocolate	Sweetness, bitterness, creaminess, liking	Chocolate shapes (round, angular; within-participants factor) did not show significant influence on post-taste ratings	None	No
Carvalho & Spence 2018	287	Extrinsic shape	Shapes of coffee cups (tulip, open, split; between-participants factor)	Arabica coffee	Aroma, sweetness, acidity, & liking	None	Aroma (tulip > open, split) Sweetness (split > tulip, open) Acidity (split > tulip, open) Liking (tulip, open > split)	Ambiguous
Machiels, 2018	S1: 82 S2: 89	Extrinsic shape	S1: Drinking cup (angular, round; between-participants factor) S2: Drinking cup (angular, round;	S1: Strawberry-flavoured	S1: Sweetness, sourness, smell Intensity, taste	S1: Sweetness, sourness,	S1: None S2: Bitterness (angular > round)	Partial - Only bitterness ratings in Study

			between-participants factor)	butter milk drink S2: Caffeinated soft drink	Intensity, liking, strawberry Flavour S2: Sweetness, sourness, bitterness, smell intensity, taste intensity, taste smoothness, liking	smell intensity, taste Intensity, liking, strawberry Flavour S2: Sweetness, sourness, smell intensity, taste intensity, taste smoothness, liking		2
Mielby et al., 2018	401	Extrinsic colour	Receptacle colour (red, black; within-participants factor), receptacle weight (light, heavy; within-participants factor)	Flavoured non-alcoholic beer	Liking, sweetness, sourness, bitterness, carbonation	Receptacle colour: sweetness, sourness, bitterness Receptacle	Carbonation (red > black) Liking (red > black)	Partial - Only carbonation ratings

						weight: liking, sweetness, sourness, bitterness, carbonation		
Sugrue & Dando, 2018	109	Intrinsic colour Extrinsic colour	Cider colour (red, green, un-dyed yellow; between-participants) Label colour (green, red, no-label; within-participants)	Cider	Sweetness, sourness, fruitiness, apple flavour, bitterness, body/ mouthfeel, refreshing, serving temperature	Cider colour: Other than temperature , body/mouth feel Label: Other than sweetness, fruity, apple flavour	Cider colour: Temperature (red. un-dyed yellow > green), body/mouthfeel (red > green, un-dyed yellow) Label: Sweetness, fruity, apple flavour (red > no-label)	Partial - Only some ratings/ conditions

Velasco et al., 2018	188	Extrinsic shape	Typefaces (round, angular; within-participants), contrast (thick, thin; between-participants)	Jellybeans	Sweetness, sourness, intensity, liking	Intensity, liking	Sweetness (round > angular; thick > thin) Sourness (angular > round; thin > thick)	Yes
Zellner et al., 2018	60	Extrinsic colour	Wrapper colour (red, green, orange, purple/pink; between-participant)	Spun sugar candy	Sweetness, flavour intensity, wrapper liking, candy flavour, liking	Sweetness, flavour intensity, wrapper liking, candy flavour, liking	None	No
Carvalho & Spence 2019	E1: 82 E2: 92 E3: 272	Extrinsic colour	E1: Cup colour (pink, white; between-participants) E2: Cup colour (pink, white; between-participants) E3: Cup colour (pink, white, yellow, green; within-participants), two coffees (Brazilian coffee: high sweetness; low acidity, Kenyan	Espresso coffee	Sweetness, acidity, liking	None	E1-2: Sweetness (pink > white), acidity (white > pink), liking (pink > white) E3 (Brazilian coffee: high sweetness; low acidity): Sweetness (pink > other colours), acidity (yellow, pink, white > green) E3 (Kenyan coffee: low-to-medium	Partial - But effects differ in coffee types

			coffee: low-to-medium sweetness; high acidity)				sweetness; high acidity): Sweetness (yellow, green > pink), acidity (pink > green)	
Hansen, 2019	E1: 110 E2: 81 E3: 123	Extrinsic colour	E1: Cup colour: blue, yellow) × Mindset (high-level, low-level) between-participants design E2: Cup colour: blue, yellow; within-participants) × Mindset (high-level, low-level; between-participants) × Flavour (sour lime, standard; between-participants) E3: Cup colour: blue, red) ×	E1: Sparkling water E2: Energy drink E3: Coffee	E1: Rrefreshment, intensity, sweetness, bitterness, sourness, the overall quality of the water E2: Sourness	E1: intensity, sweetness, bitterness, sourness, the overall quality of the water E2: None	E1: Refreshing (blue > yellow when the high-level construal is primed) E2: Sourness for the standard (but not sour lime) energy drink (yellow > blue when the high-level construal is primed) E3: Hotness (red > blue when the high-level construal is primed)	Partial - Only when the high-level construal is primed and the flavour is standard

			Mindset (high-level, low-level) between-participants design		E3: hotness, strong, intense, nutty, fruity, bitter, likeable	E3: Not reported		
Huang et al., 2019	32	Intrinsic colour (virtual)	Virtual tea colour (Chinese green tea, red tea)	Two types of tea (Chinese green tea, Chinese red tea)	Sweetness, sourness, bitterness, saltiness, astringency, pleasantness, familiarity	Sweetness, sourness, bitterness, saltiness, astringency, pleasantnes s, familiarity	None	No
Pellegrino	65	Intrinsic	Food colour (blue, white, green),	Dinner mint-	Cooling	None	Cooling intensity (blue > white, green;	Yes

& Luckett, 2019		colour	food odour (minty odour, no odour) All factors manipulated as between-participants	style confectionary	intensity		mint odour > no odour)	
Reinoso Carvalho et al., 2019	E2: 153	Intrinsic colour	Beer colour (dark, pale)	Beer	Sweetness, bitterness, sourness, alcohol strength, body, liking	Sweetness, bitterness, sourness, alcohol strength, body, liking	None	No

Wang et al., 2019	331	Extrinsic colour Extrinsic music Intrinsic aroma	Bottle colour (neon, pink, yellow), music (none, sweet soundtrack, bitter soundtrack), aroma concentration (none, medium, high) All factors manipulated between-participants	Apple elderflower fruit beverage	Sourness, sweetness, bitterness, liking	No significant effect of colour for all measures	Sweetness (no music, sweet-soundtrack > bitter-sound track; medium aroma > no aroma Bitterness (no aroma > medium aroma) Sourness (high aroma > medium aroma)	No
Bschaden et al., 2020	S1: 66 S2: 159	Extrinsic colour	S1: Ambient illumination (bright, dim) S2: Ambient illumination (bright, dim), tablecloth (present, absent)	Tomato soup	Saltiness, sourness, sweetness	S1: Sourness, sweetness S2:Saltiness, sourness, sweetness	S1: Saltiness (bright > dim)	Partial - Only saltiness ratings in S1

de Sousa et al., 2020	146	Extrinsic shape	Typefaces of packaging labels (round, angular; between-participants)	Specialty coffee	Sweetness, acidity, liking	Sweetness, liking	Acidity (angular > round)	Partial - Only acidity ratings - Non significance for sweetness
Sakai, 2020	23	Intrinsic colour (virtual)	Colour of sushi (blue, red, yellow, white; within-participants)	Tuna sushi	Palatability, intensity of fishy smell	None	Palatability (yellow, white > red, blue) Intensity of fishy smell (red > white, yellow)	Ambiguous
Sousa et al., 2020	174	Extrinsic colour Extrinsic shape	Color (pink, green; between-participants) Shapes (round, angular; between-participants) of coffee packaging labels	Coffee	Sweetness, acidity, liking	Colour (pink, green; between-participants) and shapes (round, angular; between-participants) of coffee	None	No

						packaging labels did not significantly influence post-taste ratings (sweetness, acidity, liking)		
Chen et al., 2020	41	Extrinsic colour and shapes	VR environments (sweet-congruent visual cues, bitter-congruent visual cues, neutral; within-participants)	Grenadine syrup diluted with water	Sweetness, bitterness, sourness	Bitterness, sourness	Sweetness (sweet-congruent visual cues > bitter-congruent visual cues, neutral)	Partial - Only sweetness ratings
Kpossa & Lick, 2020	432	Extrinsic colour Intrinsic	Plate colour (white, black; between-participants), Food colour (green, pink, light brown, dark	Macaron	Sweetness, creaminess, crunchiness,	Plate colour: Sweetness,	Food colour: Creaminess (Off-white > pink, yellow) Complex interactions of plate colour	Partial - Creaminess ratings when the

		colour	brown, yellow, off-white; between-participants),		greasiness	creaminess, crunchiness, greasiness Food colour: Sweetness, crunchiness, greasiness	with food colour found in greasiness rating	manipulation sense is intrinsic
Ueda et al., 2020	E1: 13 E2: 13	Intrinsic colour (virtual food luminance)	The magnification of luminance distribution of (virtual) foods (*K* = 0.5, 2.0, and 3.0 times). *K* indicates the magnification factor.	E1: Two kinds of baumkuchen E2: Two kinds of tomato ketchups	E1: Moistness, deliciousness, sweetness E2: Watery, tomato flavour, and acidity	E1: Sweetness E2: Tomato flavour, acidity	E1: Moistness and deliciousness (3.0 condition > 2.0 condition > 0.5 condition; ratings increased as the luminance histogram was increased) E2: Watery (3.0 condition > 0.5 condition)	Partial - Only certain ratings - Non significance for sweetness and acidity
Wang et al., 2020	32	Intrinsic colour (virtual drink colour)	Virtual drink color (light brown, dark brown; within-participants factor) Sucrose level (4%, 8%; within-participants factor)	Black cold-brew coffee	Sweetness, creaminess, coffee liking	Sweetness, liking	Creaminess (light brown > dark brown) only when the sucrose level is 4%	Partial - Only when the level of sweetness is low - Only

								creaminess rating
Blackmore et al. ,2021	74	Extrinsic shape (label typeface) Intrinsic colour (beer colour)	Beer colour (light, dark; within-participants factor) Label typeface (round, angular; within-participants factor)	Beers (light mild, light bitter, dark mild, dark bitter)	Bitterness, refreshment, liking and body.	Label typeface: Bitterness, refreshment, liking, body.	Bitterness (dark > light) Refreshment (light > dark) Liking (light > dark) Body (dark > light)	Partial - Only for intrinsic sensory cues

Carvalho & Spence 2021	183	Extrinsic colour	Cup finish (gold, platinum, bronze, white), coffee type (Kenyan, Brazilian)	Coffee (Kenya, Brazil)	Sweetness, flavour, metallic, aroma	None	Sweetness (bronze > others) Flavour (bronze > gold = white > platinum) Metallic (platinum > gold = bronze > white) Aroma (gold = bronze > platinum = white)	Ambiguous
van der Heijden et al., 2021	152	Extrinsic colour	Ambient illuminance (dim, bright; between-participants factor)	4-course menu	Overall taste intensity, pleasantness	Pleasantnes s	Overall taste intensity (bright > dim)	Yes
Cornelio et al., 2022	32	Extrinsic colour (ambient color	Ambient colour virtual environment (red, blue, neutral), food shapes (round, angular), sugar content (neutral, sweet)	Kiki (angular) & Bouba (round) jelly samples	Sweetness, pleasantness	Food shapes: sweetness (neutral	Sweetness (round > angular for sweet samples) Sweetness (neutral > blue for neutral samples)	Partial - When samples are sweet or neutral

		virtual environment Intrinsic shape (food shapes)	All factors manipulated within-participants			samples), pleasantness Ambient colours: sweetness (sweet samples), pleasantness		
Otterbring et al. 2022	20	Extrinsic shape	Typefaces of containers (round, angular; between-participants), flavour (lemon, vanilla; within-participant)	Ice-creams (lemon, vanilla)	Sweetness, sourness	Typefaces (round, angular; between-participants factor) of containers did not significantly affect taste perception of ice-	None	No

						cream		
Sugimori & Kawasaki, 2022	E1: 37 E2: 40 E3: 58	Extrinsic colour	E1: Wrapping paper color (black, pink) E2: Wrapping paper color (black, pink) E3: Cup color (clear blue, clear)	E1: milk chocolate (sweet, bitter) E2: two types of chocolates (bitter, less bitter) E3: two types of green teas (bitter, less bitter)	E1: Sweet-bitter scale (not sweet/ bitter at all to very sweet/bitter) E2: Sweetness, bitterness E3: Sweetness, bitterness	E1: Sweet-bitter scale E2 (less bitter chocolate): Sweetness, bitterness E3 (less bitter green tea): Sweetness, bitterness	E1: None E2 (Bitter chocolate): Sweetness (pink > black), bitterness (black > pink) E3 (Bitter green tea): Sweetness (clear > clear blue), bitterness (clear blue > clear)	Partial - When food is bitter - When participants are not supertasters
Iuri et al., 2022	230	Intrinsic shape	Chocolate shapes (round, angular; between-participants factor)	Five chocolates containing 30, 40, 50, 60, & 70% of cocoa.	Sweetness, bitterness, liking, creaminess	Sweetness, bitterness, liking	Creaminess (round > angular)	Partial - Only creaminess rating
Wang et al., 2022	51	Intrinsic colour	Saturation of food color (high, low), roughness of food (high, low), food	Hot sauces	Spiciness	None	Spiciness (high saturation > low saturation; high roughness of food >	Yes

			visibility (high, low) *all factors varied within-participants				low roughness of food) when the condition is high-visibility	
Wu et al., 2022	16	Extrinsic colour	Ambient colour virtual environment (black, green, orange, pink, purple, red, yellow, and blue; within-participants)	Black tea	Sweetness, sourness, saltiness, bitterness	Sweetness, sourness, saltiness, bitterness	None	No
Annette & Stafford, 2023	47	Extrinsic colour	Bowl colour (red, blue, white; within-participants), group (picky eaters, non-picky eaters; between-participant)	Food snack (Salt & Vinegar Crisps)	Saltiness, flavour intensity, desirability	Flavour intensity	Saltiness (blue, red > white only for picky-eaters) Desirability (blue > red only for picky-eaters)	Partial - Only picky eaters - Not perfectly following colour-taste correspondences
Sakarya &	S1: 34	Extrinsic	S1: Coloured cups (white, brown,	Coffee	S1-3: Smell	S1: Liking	S1: Smell (white > blue), softness	Partial

Dortyol, in press	S2: 32 S3: 30	colour	blue; within-participant) S2: Weight of cups (normal, heavy; within-participants) S3: Coloured cups (white, brown, blue; within-participants) × Weight of cups (normal, heavy; within-participants)	(fragrant), liking, softness (aroma), intensity	S2: Liking, softness S3: Liking, softness, intensity	(blue > white), intensity (white > blue, brown) S2: Smell & intensity (heavy > normal) S3: Smell (heavy brown > normal blue)	- Only some ratings/ conditions

Note: E = Experiment. S = Study.