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Colored backgrounds affect the attractiveness of fresh produce, but not it's perceived color

Hendrik N.J. Schifferstein [a,*], Bryan F. Howell [b], Sylvia C. Pont [c]

[a] Department of Industrial Design, Delft University of Technology, Landbergstraat 15, 2628 CE Delft, The Netherlands
[b] Department of Industrial Design, School of Technology, Ira R. Fulton College of Engineering, Brigham Young University, 265 Crabtree Building, Provo, UT, USA
[c] Department of Industrial Design and Perceptual Intelligence Lab, Delft University of Technology, Landbergstraat 15, 2628 CE Delft, The Netherlands

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ABSTRACT

The color of the background on which products are presented may affect their perceived attractiveness. We presented five different vegetables (tomato, carrot, yellow bell pepper, cucumber, eggplant) on four different background colors (orange or blue, either light or dark). Although the backgrounds did not affect the direct color perception of the vegetables, they did affect their perceived attractiveness, with quite different backgrounds proving optimal for the various vegetables. These outcomes suggest that it is difficult to find non-neutral background colors on which a large number of vegetables can be presented in an optimal way.

1. Introduction

In order to stimulate the sales of fresh produce in retail stores, it is important that the products are presented in an attractive manner, so that they look appetizing. One important aspect for an attractive presentation concerns the color of the materials on which products are presented. In many retail settings a number of fruits or vegetables are presented on a tray or in a crate, possibly covered with a transparent material. Alternatively, the produce may be packed in a fully transparent packaging that is presented on retail shelves or in common crates. Hence, packaging materials are not only important to protect products during transport and handling, but together with the trays, crates, or shelves on which products are presented, they form the colored backgrounds against which potential buyers and consumers evaluate fresh produce.

Theoretically, the perceived color of objects may be affected by the color of the background on which it is presented. In the literature on fundamental visual perception mechanisms, two well-known effects regarding background and foreground colors are called color assimilation and simultaneous color contrast (e.g., Stockman & Brainard, 2009). In the case of color assimilation the color of an area is perceived to be closer to that of the surround than when viewed in isolation, whereas in the case of color contrast it has shifted in the opposite direction. Hence, the perception of produce presented on a colored background might change, depending on the color of the background on which it is presented.

However, many studies in visual perception research have been performed using two-dimensional and quite abstract stimuli, instead of using realistic 3D objects. The classical papers by Edwin Land (Land, 1959a,b,c; Land & Daw, 1962) already made clear that color percepts of natural, complicated images are dependent on the interplay of elements over the total visual field. Recent studies showed that for real, 3D objects in articulated scenes color constancy under illuminant changes is enhanced relative to 2D setups (Hedrich, Bloj, & Ruppertsberg, 2009). In studies with 3D objects the background had little effect on perceived object colors in contrast to 2D scenes (Allred & Olkkonen, 2013), and the hue could be matched quite accurately for smooth and glossy as well as matte and rough objects (Giesel & Gegenfurtner, 2010).

Nonetheless, visual as well as spectral color measurements of orange juice dilutions have been shown to be influenced by the background on which they are presented (Meléndez-Martínez, Vicario, & Heredia, 2005). In this case, however, the effect of background is likely being caused by an optical mechanism: Because orange juice is fairly translucent, the background shines through the fluid. Hence, this situation is different from when a colored background is put behind an (almost) opaque object.

As concerns aesthetic responses (preference, liking, attractiveness) with 2D stimuli, Schloss and Palmer (2011) have shown that all foreground colors are generally liked when presented on a cool colored background (e.g., blue), while only the cool foreground

* Corresponding author.
E-mail address: h.n.j.schifferstein@tudelft.nl (H.N.J. Schifferstein).

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colors are liked when presented on a warm colored background (e.g., orange). If this also holds for 3D objects, the attractiveness of fresh produce in retail stores is likely to depend highly on the colors of the materials on which it is presented.

Nonetheless, it seems as if the colors of the fresh produce displays in most outlets have received only limited attention in everyday retail practice. In many cases fresh produce is presented in plastic crates with relative neutral, uniform colors, such as black or grey, which seem to be the result of practical concerns during transportation, and not of explicit considerations of the way in which retailers can optimize product presentation. Alternatively, fruits and vegetables may be presented on wood-like materials, probably with the intention to evoke associations of naturalness, even though the material may be difficult to clean, accommodate harmful insects, and damage the produce through wood splinters. Hence, it is important to investigate to what extent the consumer perception of produce depends on the colors of background materials, in order to determine whether retail managers should take these effects into account when displaying their products.

Although we investigate color in the present study as a color perception phenomenon, it is important to realize that consumers may attach different types of meanings to colors. For instance, natural variations in product color may be associated with ripeness and sour-sweet ratio (green, yellow, red) and with spoilage (browning) for produce. In this case, the colors are directly instrumental in communicating product properties. Furthermore, for many processed foods the colors of its packaging may be associated with particular product variants or flavors (Ngo, Piqueras-Fiszman, & Spence, 2012; Piqueras-Fiszman, Velasco, & Spence, 2012; Velasco et al., 2014) or with particular product properties (Roullet & Droulers, 2005). In this case, the packaging color itself can facilitate the identification of certain product aspects. Besides, colors may also have a symbolic value and generate particular cognitive associations (Ares & Deliza, 2010) and these associations may differ between cultures (Madden, Hewett, & Roth, 2000). For instance, the color red is a signal for danger in many societies, which may decrease consumption probability (Genschow, Reutner, & Wänke, 2012; Reutner, Genschow, & Wänke, 2015), but in China the color red is likely to have an opposite effect, because there it is associated with good luck and prosperity. Furthermore, colors may also bring their own hedonic evaluations (Madden et al., 2000; Valdez & Mehrabian, 1994; Whitfield & Wiltshire, 1990), even though color preferences highly depend on the context in which they are perceived (e.g., the size and the type of object that carries the color; Holmes & Buchanan, 1984). Although color meaning could have an impact on the perceived attractiveness of colors and objects, we focus here mainly on how product evaluations are affected by the visual perception of background color.

In the current paper we investigate the effects that background colors have on the direct color perception and the evaluation of the attractiveness of fresh vegetables. We evaluate whether principles demonstrated in the visual perception literature can be extrapolated to the presentation of fresh produce and if product attractiveness judgments are affected. Because we would like our study to be relevant for retail practice, we asked a professional designer to select the background colors for the test.

2. Method

2.1. Participants

Forty-four volunteers, 19 females and 25 males, participated in the study. The females varied in age between 18 and 29, with a mean age of 20.7 years. The males varied from 21 to 31, with a mean age of 23.5 years. 93% of respondents were students of Brigham Young University (BYU), 7% were friends or family members associated with the students. The majority of participants (61%) were undergraduate students from the Industrial or Graphic Design Departments, and another significant part (23%) had an engineering/technical background. The remainder (16%) came from a variety of backgrounds. All participants were screened for color blindness using an Ishihara test before participating. The experiment was approved by the BYU Institutional Review Board (IRB) for Human Subjects (study number E15416).

2.2. Stimuli

The study was performed with five different vegetables, each in a different color: tomato (red), carrot (orange), bell pepper (yellow), cucumber (green), and eggplant (blue/purple). These products were chosen, because they were prototypical examples of the vegetables in these color categories, had similar smooth skin textures and had fairly homogeneous colors over their whole surface.

We used an elaborate procedure to identify the colors from the NCS atlas that best describe the actual colors for each of the five vegetables as objectively as possible. These assessments were necessary to select the pages of the color atlas that we provided to the participants in the color matching task. A professional designer (the second author) removed swatches from the NCS color atlas and held them close to the vegetable sample in the experimental setup, so that the lighting was the same as during the experiment. He varied the comparison location over the sample, to take into account any color variation over the sample surface. By stepping back and forth through the swatches of the atlas, the best overall match was determined for each sample. The selection thus made consisted of the following hues: tomato (Y80R), carrot (Y50R), bell pepper (Y10R), cucumber (G40Y), and eggplant (R).

The Natural Colour System (NCS) is a logical, perception-based color notation system. The NCS codes describe a color by its hue, blackness and chromaticness (see Fig. 1 for a photograph of two of its pages). The hue is described by its degree of similarity to the elementary colors yellow, red, blue, and green. Blackness is how dark the hue is and chromaticness is how saturated the hue is. On each NCS atlas page (41 pages in total), the approximately 50 unique color swatches exhibit many variations in blackness and chromaticness, but the hue is constant.

2.3. Backgrounds

In order to select background colors for the present study, we wanted to use blue and orange as backgrounds, based on the experimental finding that all foreground colors are liked when presented on a cool colored background, while only the cool figure colors are liked when presented on a warm colored background (Schloss & Palmer, 2011). Hence, we expect that products with warm colors (red, orange, yellow) are perceived as less attractive when presented on an orange than on a blue background, whereas products with cool colors (green, blue) are perceived as equally attractive when presented on the different backgrounds.

In addition, we make use of the finding that simultaneous contrast can enhance a product's appeal when presented on a background that contrasts with the presented product (Lyman, 1989). Therefore, we will use both light and dark background colors and we expect that products with dark colors are perceived as more attractive when presented on a light background than on a dark background, while the opposite is true for products with light colors.

In order for our finding to be relevant for design practice, we asked a professional designer (the second author) to select blue

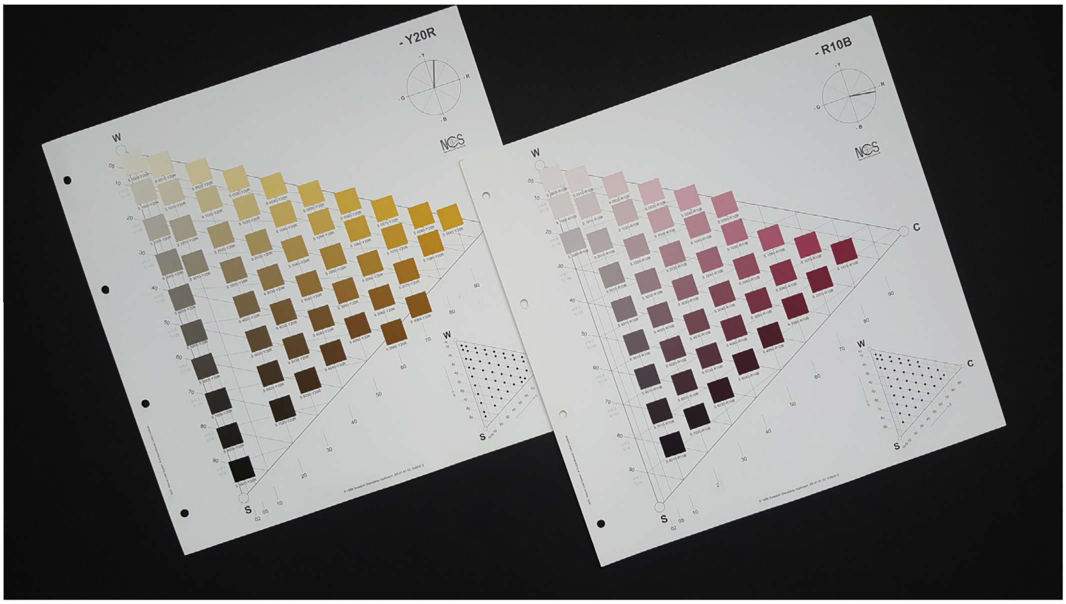

Fig. 1. Two pages of the NCS atlas, showing two different hues. At each page the blackness and chromaticness vary over the pages in vertical and horizontal directions, respectively.

and orange colors that were either light or dark ($2 \times 2 = 4$ background colors) and that would be appropriate for effectively displaying an assortment of all five vegetables in different colors in an optimal way, according to his personal opinion.

In the process of selecting the four background colors, the designer photographed all five chosen vegetables in one shot and transferred that image to an online digital tool color.adobe.com. This tool places each color on a single color wheel, providing an estimated visual and numerical understanding of the spatial relationships of these five vegetable hues and permitting identification of the vegetables' complementary colors, which lay directly opposite of the identified colors on the wheel. The complement of any selected color provides the strongest color-contrast to the selected color. Designers understand that objects appear more vivid and richly colored when placed on somewhat neutral, single hued surrounds that provide hue, chromaticness and blackness contrast (Brown & MacLeod, 1997). Hence, providing a contrasting surround is an important step in presenting an object in its most attractive manner.

While defining a complementary color for an individual vegetable color is fairly simple, accomplishing the same for a family of variable colors is quite complex. With the insights gained from the color wheel, the designer selected complementary hue pages from the NCS color atlas and passed the vegetables over the pages to identify which four background colors effectively presented the family of vegetables. Because all the vegetables have saturated colors, the contrasting colors were low in saturation, having a noticeable grey component in them. A significant amount of visual averaging occurred between the different vegetables and multitude of color swatches during the final color background selection. For example, the selected swatch may not have been an ideal visual match with a tomato and a bell pepper, but it was equally acceptable with both, whereas another color swatch might have been more visually attractive with the tomato but less so with the pepper. In this search process, balancing the blackness and chromaticness levels for the family of vegetable colors was the primary challenge, while choosing the hue was easier. The final selection of background colors consisted of: Light orange (2010 Y20R), Dark orange (6020 Y20R), Light blue (2020 R80B), and Dark blue (6020 R80B).

2.4. Procedure

The study was conducted in a dark room on the BYU campus with blacked out windows and no peripheral lighting. The only sources of light were artificial lights in the testing cubicles. Sessions were conducted in groups of 4 or 5 participants simultaneously. When the participants entered the room, they seated themselves at one of the five available viewing cubicles.

Each cubicle was a five-sided box with white paper walls and ceiling and a mid grey paper table surface. The cubicles were 115 (length) $\times$ 50 (width) $\times$ 50 (height) cm and illuminated by two 120 cm long fluorescent tubes. A bulk pack of 10 lamps was purchased for the test, so that each cubicle had identical lamps from the same manufacturing session and the same number of in-use hours. Each lamp was specified at 40 W, 2500 lm with a color-rendering index of 90 and a color temperature of 5000 K. The tubes were T12 size and mounted as a pair in a white sheet metal housing.

The luminance level in each cubicle measured 1150 lm at the center of the booth from the left and right sides, 25 cm from the back wall and at the table surface, as measured with a GreenLee digital light meter. The luminance level for each booth was managed by a simple aperture system of two sliding foam core sheets placed directly below the lamps.

In the cubicle, one whole sample of each vegetable was presented on a semi-matte A4 NCS paper. These sample papers had a coating, which made them less susceptible to being spoilt by any juices coming from the vegetables in case they were damaged. The samples on the paper were placed against the back wall of the viewing booth and in front of the participant at a distance of about 50–60 cm. Participants were instructed to look at the produce sample without touching it.

Color matching session

First of all, we determined whether any potential changes in product attractiveness were based on shifts in a vegetable's perceived color as viewed on the four differently colored backgrounds. In the color-matching sessions, participants were asked to pick the color that best represented the color of the product from three pages of the NCS atlas, which were presented right in front of the participant. One hue page contained the matching color as determined by the designer's judgment. The other two pages were the adjacent hue pages from the NCS atlas. For evaluating the color of the tomato participants were presented with NCS pages Y70R, Y80R and Y90R, for the carrot with Y40R, Y50R, and Y60R, for the bell pepper with Y, Y10R, and Y20R, for the cucumber with G30Y, G40Y, and G50Y, and for the eggplant with C = 00/C = 02, R, and R10B. The three NCS pages were presented to the participants in different orientations for each sample and participants were allowed to move them around as they wished.

A mid grey mask was created for each atlas page covering the numerical swatch identifications and other incidental printing on the page yet allowing each swatch to be clearly seen (see Fig. 2). This mask was hinged on one side allowing the respondents to lift the mask up to identify the code for their chosen color swatch. Furthermore, participants were provided with a 10 × 10 cm mid grey hand held mask that allowed them to view each color sample separately. They were asked to note down the NCS color code of the matching color. They had up to 45 s to evaluate each sample.

Product evaluation session

In the product evaluation sessions, vegetable samples were again presented on a semi-matte A4 NCS paper and respondents were asked to judge the attractiveness of the produce samples by marking a box for each of the response scales listed on the form. The response scales measured the degree to which the produce sample looked appetizing, healthy, fresh, natural, beautiful, tasty, and attractive and the degree to which the color of the produce sample looked vibrant and vivid on a 9-point scale anchored with end points 'Not at all' (1) and 'Very' (9). They had about 80 s to evaluate each sample.

After evaluating a sample in a color matching or a product evaluation session, participants handed in their forms and switched cubicles. They repeated this until they had evaluated all five produce samples. During a single round, all five vegetables were presented on the same background color. After they evaluated all five produce samples, participants were requested to leave the room while the assistants placed the samples in different viewing cubicles and on a different background.

In total, each participant finished four rounds of color assessments and four rounds of product evaluations, one round for each background color. The type of assessment alternated between consecutive rounds. The sequence of the background colors that was used in the eight rounds was determined by chance and was different for each group of 4 or 5 participants.

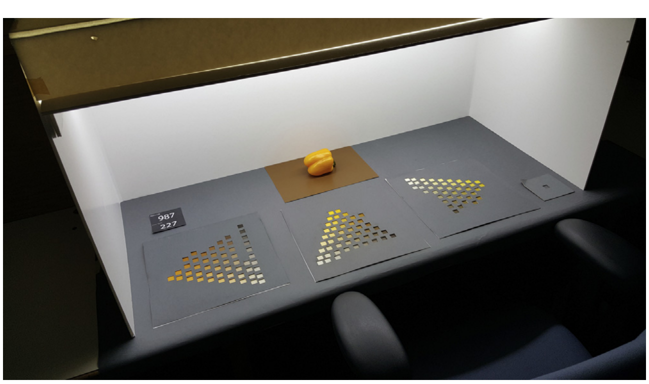

Fig. 2. Overview of a testing cubicle prepared for the color assessment task, showing a card indicating the background color and vegetable codes, the vegetable presented on a background sheet, the three NCS pages with masks, and the small grey handheld mask.

2.5. Data analysis

Color assessments were recorded as NCS codes, which consist of a percentage value for blackness (from white to black), for chromaticness (from grey level to saturated), and for hue (from yellow to red for tomatoes, carrots, and bell peppers; from red to blue for eggplants; from green to yellow for cucumbers). We analyzed these three percentage values in a doubly multivariate ANOVA with repeated measures for Products and Backgrounds in IBM SPSS version 22. Although the hue percentage values refer to the balance between different hues for different products, this does not hinder us in demonstrating whether background color affects the perception of the hue for the various products, because the MANOVA takes into account the interdependence between the dependent measures. We used the F-values corresponding to Wilks' Lambda to evaluate multivariate effects.

The ratings on the nine response scales were analyzed by repeated measures ANOVA. In accordance with Stevens (2002), we corrected the degrees of freedom with the Greenhouse – Geisser ε if $\varepsilon < 0.7$, and we averaged the ε values from Greenhouse – Geisser and Huynh – Feldt, when $\varepsilon > 0.7$ in subsequent repeated measures ANOVAs of single variables. Differences between individual stimuli were investigated by a posteriori t-tests with Bonferroni adjustment.

3. Results

3.1. Color matching

The multivariate tests of the three percentage values describing the NCS-matched colors showed a significant main effect of Product [$F(12,439) = 915.0$, $p < 0.001$, $\eta^2 = 0.94$], but not for Background [$F(9302) = 0.7$, $p > 0.20$, $\eta^2 = 0.02$] nor for the Product × Background interaction [$F(36,1484) = 1.3$, $p > 0.15$, $\eta^2 = 0.03$]. Hence, the perceived color of the vegetables in the current study does not depend on the background against which they are presented.

The colors that were selected most often by the participants for the different vegetables – with frequencies between parentheses – for tomato were 2075 Y70R (30), 2070 Y80R (24), and 1580 Y80R (21), for eggplant they were 8502 R (90) and 8010 R10B (66), for carrots they were 0570 Y60R (32), 1070 Y60R (25) and 0570 Y50R (18), for bell peppers they were 0585 Y20R (61) and 0580 Y20R (58), and for cucumbers they were 3060 G40Y (21), 4050 G40Y (17), and 4550 G40Y (15).

3.2. Product evaluations

Responses on the nine response scales were generally highly correlated. Principal components analysis yielded only a single factor with Eigenvalue > 1, with this single factor explaining 73% of total variance. This outcome suggests that the response scales tend to measure a single underlying construct. The attribute that loaded highest on this factor was the attractiveness item (0.92). Therefore, we decided to present the analyses here only for this item, as the outcomes for the other items are highly similar.

Repeated measures ANOVA for the attractiveness ratings showed a significant Product × Background interaction [$F(5.3, 222.7) = 38.4$, $p < 0.001$, $\eta^2 = 0.48$]. The main effects of Product [$F(3.4, 142) = 1.8$, $p > 0.10$, $\eta^2 = 0.04$] and Background color [$F(2.7, 112) = 1.8$, $p > 0.15$, $\eta^2 = 0.04$] did not reach significance. The absence of the main effect of background color indicates that none of the background colors is better than the others for displaying all vegetables. At the aggregate level, the mean attractiveness rating for the vegetables presented on the light blue background is highest

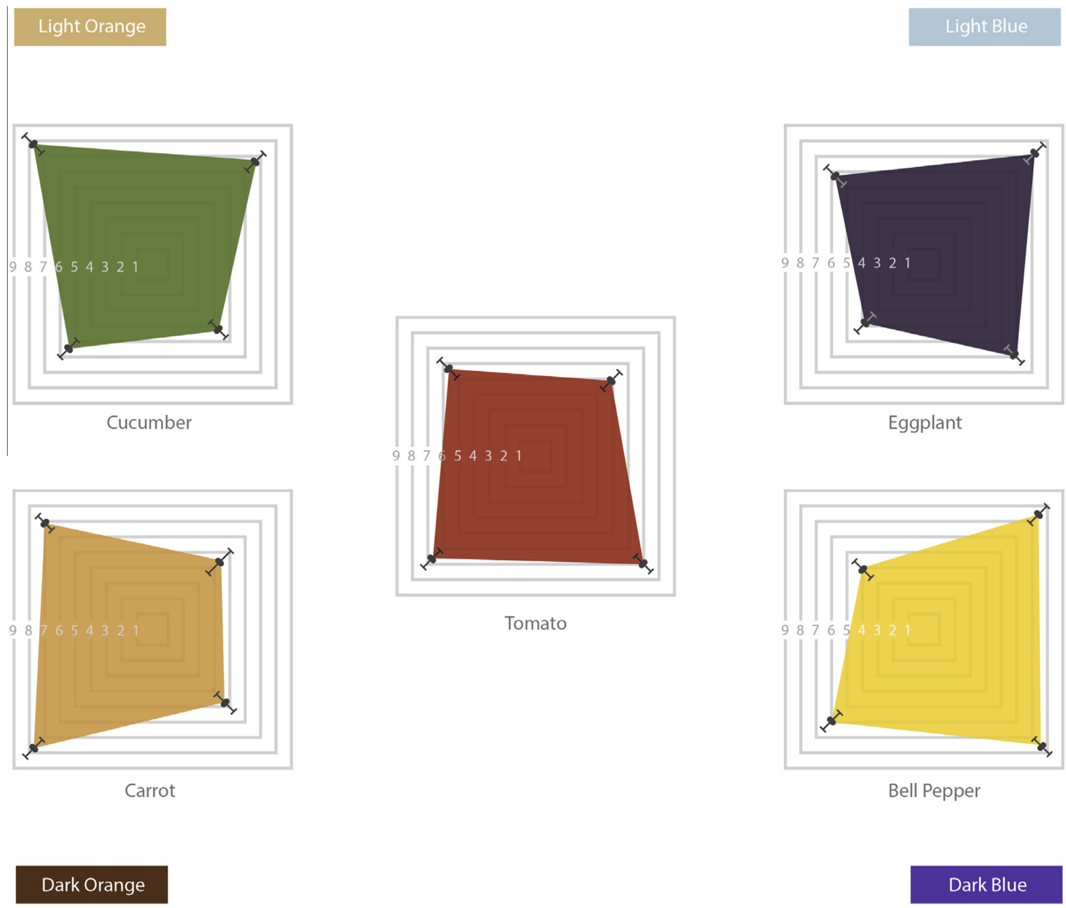

Fig. 3. Mean attractiveness ratings (±2 SEM) for five vegetables with different colors, presented on four different backgrounds. The center square of each plot represents a rating of 1 and the outer square a rating of 9. The four diagonal axes represent the four background colors: light orange (upper left), dark orange (lower left), dark blue (lower right), and light blue (upper right).

(6.1), followed by light orange (6.1) and dark blue (6.0), but these means are not significantly better than for dark orange (5.9), which has the lowest mean rating. Similarly, the absence of the main effect for product indicates that the five vegetables do not differ in attractiveness: The mean attractiveness ratings were highest for the bell pepper (6.2), followed by the tomato (6.1), the cucumber (6.1), the carrot (6.0), with lowest ratings for the eggplant (5.7), but these differences were not statistically significant.

The significant interaction between vegetables and backgrounds is further explored in Fig. 3, which shows the mean attractiveness responses for the five vegetables presented on the four different backgrounds. This figure shows that mean attractiveness ratings for each vegetable differ quite substantially for the four backgrounds. If we calculate the difference between the mean ratings for the most attractive versus the least attractive presentation for each vegetable, these difference values vary from 2.05 for the tomato to 3.61 for the eggplant.

The attractiveness ratings in Fig. 3 do not support the expectations based on Schloss and Palmer (2011) that products with warm colors would be perceived as less attractive when presented on an orange than on a blue background. For the three vegetables with warm colors, only the results for the yellow bell pepper (0585 Y20R) provide support for the hypothesis: it obtained lower ratings when presented on orange (4.0 and 6.0) than when presented on blue backgrounds (7.3 and 7.6). However, the mean attractiveness rating of the tomato (2075 Y70R) was quite high when presented on dark orange (6.7) and similar to its top rating on dark blue (7.0), and was low for both light backgrounds (5.0 and 5.7). In contrast to the hypothesis, the attractiveness of the carrot (0570 Y60R) was considerably higher on the two orange backgrounds (7.7 and 7.1) than on the blue backgrounds (4.4 and 4.9). The prediction that products with cool colors are perceived as equally attractive when presented on an orange or on a blue background was not disconfirmed in the present study, because the cucumber (3060 G40Y) was judged most attractive on the light orange background (8.0), but also looked very attractive on the light blue background (6.6), with lower ratings on the two darker backgrounds (4.4 and 5.2). For the eggplant (8502 R), however, the highest ratings were obtained on light blue (7.3) and dark blue (6.1) backgrounds, and lower ratings on the two orange backgrounds (3.7 and 5.8).

4. Discussion

4.1. Vegetable color perception

Participants assessed the vegetable colors they perceived, using a color matching task. In this task, they tended to agree more on the color samples chosen for the eggplant and the bell pepper than for the other vegetables. This suggests that the perceived color of the eggplant and the bell pepper was easier to judge than the color of the other vegetables. This might be partly due to the homogeneity of the surface color or to the degree of translucence of the product skin for the various vegetables. However, the responses might also be affected by the availability of the color samples provided in the NCS system.

In the present study the colored backgrounds on which the vegetables were presented did not affect the perceived colors of the vegetables. These outcomes are in line with several studies that have observed improved color constancy for 3D objects in situations where the perception of 2D stimuli was dependent on background color (Allred & Olkkonen, 2013; Hedrich et al., 2009). People are likely to have color expectations for the prototypical vegetables we investigated. For instance, people will expect a certain type of orange for a carrot, a dark saturated red for a tomato, and so on. Strong expectations are likely to enhance perceptual constancy for the product color (e.g., Troost, 1998), which makes color measurements resistant to contextual manipulations of the background color. This could make it interesting to explore what happens when the vegetables presented have unexpected colors instead of these prototypical ones. For instance, you can buy carrots nowadays that are white, yellow, or purple instead of orange. How will products with these unexpected colors be experienced when they are presented on differently colored backgrounds? Will their color measurements be more susceptible to context effects, because their perception is not rooted so firmly in long-term everyday practice?

4.2. Vegetable attractiveness

Although we did not find an effect of our background manipulation on the perceived color of the vegetables, we did find differences in the perceived attractiveness of the various vegetables. Each vegetable seems to have its own optimal background color(s), which typically involves a contrast in hue, blackness, and/or chromaticness. The optimal color is light orange for the cucumber (strong hue and blackness contrast), light blue for the eggplant (strong blackness contrast), light or dark blue for the yellow bell pepper (strong hue and chromaticness contrast), light or dark orange for the carrot (strong chromaticness contrast for both backgrounds and a strong blackness contrast for the dark orange background), and dark blue or dark orange for the tomato (strong hue, blackness and chromaticness contrasts).

This pattern of findings did not support the expectations based on Schloss and Palmer (2011) that products with warm colors would be perceived as less attractive when presented on an orange than on a blue background. In particular, the results for the carrot are quite contradictory to what the hypothesis predicts: Attractiveness ratings for the carrot are highest when presented on the orange backgrounds. In fact, we may observe another phenomenon here, which is that 3D object colors may become more saturated when presented on backgrounds with similar hues. This is due to the interreflections between the object presented on a background with a similar reflectance spectrum. These interreflections attenuate wavelengths for which reflectance is low. This effect would become even stronger if the 3D object was put in a box painted in the background color, because this would produce more interreflections from different directions on the different sides of the object. People tend to prefer foods with more saturated colors. This preference may have an ecological origin, because the degree of saturation of the colors of most foods decreases when foods deteriorate during the decomposition process (Lee, Lee, Lee, & Song, 2013). Hence, the vividness of the colors of food is a natural indicator of the safety, freshness, and nutritional quality of food. Therefore, an intervention that increases the saturation of the color of the vegetable is likely to increases it's perceived attractiveness. If our proposed mechanism were correct, this would suggest that vegetables might benefit most from presentation on backgrounds in similar – rather than contrasting – hues.

Furthermore, some attractiveness ratings for the vegetables might be affected by the aesthetic appreciation of the various background-object combinations. For instance, the perceived harmoniousness of color combinations might be expected to have such an effect (Ou & Luo, 2006; Wei, Ou, Ronnier Luo, & Hutchings, 2015; Wicaksono, Fu, Chen, Hou, & Ou, 2014), even though the aesthetic response to color is influenced by individual and cultural differences as well as perceptual, contextual and temporal factors (O'Conner, 2010). Thus further studies exploring other factors not pursued in this study is viable to increase our understanding of perceived produce attractiveness.

4.3. Methodological limitations

Some methodological factors may have had an impact on the measurements. For instance, being able to directly match the vegetable appearance to the samples of the color atlas may help to avoid any shift in color perception. In addition, the size of the vegetable and the proportion of background it covers are likely to have an impact on color perception: A large carrot on a small background paper may be perceived differently from a small carrot on a large paper. Also, the percentage of background surface covered depended on the viewing angle, which varied with participant movement. Furthermore, participants were provided with several types of papers to facilitate making their judgments that may have covered part of the background during their assessments. All these factors may have affected the amount of background color the participants have viewed and may have reduced any effect of the background on their color matching responses.

4.4. Implications for vegetable presentation

It would be commercially interesting to find out whether we might be able to select a background color that would support the presentation of an assortment of vegetables with multiple saturated colors. Therefore, it is disappointing that the main effect of background color was not statistically significant in the ANOVA of the attractiveness ratings. Apparently, none of these four colors made all five products look better than any of the other colors at the aggregate level. For a single background color attractiveness ratings differ substantially between the five products, but for each background there is a different vegetable that increases in attractiveness, whereas one or more other vegetables become less appetizing. Hence, finding a single colored packaging material in which various differently colored vegetables can be presented to make them all look attractive is extremely difficult.

Possibly, a different designer would have come up with a different set of background colors for presenting the current product assortment, while using the same set of selection criteria. However, any designer would have been challenged to average out a number of effects while making the final selection. In order to select a color that was good for all five vegetables, the designer would have to dismiss any colors that were unacceptable for one or more vegetables, but possibly ideal for another vegetable. Nonetheless, because each of the colors we used showed a clear attractiveness enhancement effect for one or two of the vegetables, we wonder whether other colors could be more successful in displaying the whole family of produce.

Perhaps materials with contrasting, neutral colors such as (off) white and (off)black may work well for multi-colored vegetable assortments. Because most vegetables have saturated colors, the neutral background colors contrast substantially with the vegetable colors on the hue and chromaticness dimensions. Although differences on the blackness dimension are vegetable-specific, this difference is likely to be largest when using extreme background colors (white and black) rather than colors in the middle of the neutral spectrum (mid grey). Hence, by choosing white or black backgrounds a designer is most likely to present a selection of vegetables in an optimal way. This would be in line with observations in restaurant practice, which have shown that most chefs use white plates (and occasionally black) to showcase their culinary offerings (Spence & Piqueras-Fiszman, 2014). Colored plates have indeed been tested in empirical research in restaurant settings to investigate their effect on food perception and attractiveness, but have generated mixed results (Adams, 2013; Harrar, Piqueras-Fiszman, & Spence, 2011; Piqueras-Fiszman, Alcaide, Roura, & Spence, 2012; Piqueras-Fiszman, Giboreau, & Spence, 2013).

For presentation purposes in retail practice, another useful design strategy may be that producers of multicolored vegetable assortments stick to clear plastic packaging that let the vegetable colors speak for themselves, instead of using a standard packaging material in a single color. In this case the retailers can determine for themselves on which type of background they prefer to present their merchandise, depending on local customs and availability of materials. It would be interesting to see how different packaging concepts perform on backgrounds of neutral or non-neutral colors.

Please note that in an assortment of vegetables, any target vegetable would not only contrast against the background, but also with the other vegetables in the assortment. Hence, in assortment presentation the different vegetables also function as each other's background, which may again affect their attractiveness. Moreover, in this case people might determine their attractiveness judgment for a vegetable not only on the basis of the colors of the surrounding vegetables, but also on the combinations of textures, tastes, smells, and so on.

In the present study we used sheets of paper as backgrounds for the vegetables, because they were available in standardized sizes, textures and gloss levels and – most importantly – accurate colors that could be replicated over time. However, for future studies it might be interesting to study other background formats, such as colored wrappers, trays, boxes, crates, or shelves that will mimic retail situations more closely. These more encompassing formats will provide background reflections from multiple directions on the vegetable surface, hence enhancing the effect of the background color.

Another interesting venue to explore would be to determine the effects of using different types of materials as backgrounds for the vegetable assortments. Different materials do not only have different colors, but they also carry a variety of connotations that influence the cognitive and emotional experiences of consumers (Karana, Hekkert, & Kandachar, 2009). We already mentioned the connotations of wood with nature and authenticity. Analogously, polished or muted steel may be associated with hygiene and quality, stones like marble and granite with robustness and luxury, plastics with hygiene but also with cheapness, and textiles with craftsmanship and distinctiveness. Hence, the same vegetable presented on different material backgrounds with similar color palettes may produce different attractiveness responses. These individual material associations may help retailers to market specific types of products. For instance, if the use of textiles indeed communicates a sense of uniqueness and individuality, textiles might be used to support sales of produce with unexpected shapes that consumers may regard as undesirable or less attractive, but that are in fact as healthy and appetizing as the prototypically shaped vegetables.

5. Conclusion

While the hypotheses were not confirmed, the present study has opened up a number of exploratory directions that could influence the way in which foods are presented in buying and consumption settings. Ideally, these changes will be used to support healthy eating habits and to improve the quality of eating experiences for consumers, while simultaneously sustaining the profitability of food services, restaurants, and food retailers.

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References

Adams, S. (2013). *How to rescue NHS food? Put it on a blue plate: Simple switch has helped elderly and weak patients eat nearly a third more*. Retrieved June 2016, from http://www.dailymail.co.uk/news/article-2520058/How-rescue-NHS-food-Put-blue-plate-Simple-switch-helped-elderly-weak-patients-eat-nearly-more.html#ixzz4BhrHe87W.

Allred, S. R., & Olkkonen, M. (2013). The effect of background and illumination on color identification of real, 3D objects. *Frontiers in Psychology, 4*, 821.

Ares, G., & Deliza, R. (2010). Studying the influence of package shape and colour on consumer expectations of milk desserts using word association and conjoint analysis. *Food Quality and Preference, 21*(8), 930–937.

Brown, R., & MacLeod, D. (1997). Color appearance depends on the variance of surround colors. *Current Biology, 7*(11), 844–849.

Genschow, O., Reutner, L., & Wänke, M. (2012). The color red reduces snack food and soft drink intake. *Appetite, 58*(2), 699–702.

Giesel, M., & Gegenfurtner, K. R. (2010). Color appearance of real objects varying in material, hue, and shape. *Journal of Vision, 10*(9), 1–21.

Harrar, V., Piqueras-Fiszman, B., & Spence, C. (2011). There's more to taste in a coloured bowl. *Perception, 40*(7), 880–882. http://dx.doi.org/10.1068/p7040.

Hedrich, M., Bloj, M., & Ruppertsberg, A. I. (2009). Color constancy improves for real 3D objects. *Journal of Vision, 9*(4), 1–16.

Holmes, C. B., & Buchanan, J. (1984). Color preference as a function of the object described. *Bulletin of the Psychonomic Society, 22*, 423–425.

Karana, E., Hekkert, P., & Kandachar, P. (2009). Meanings of materials through sensory properties and manufacturing processes. *Materials & Design, 30*, 2778–2784.

Land, E. H. (1959a). Color vision and the natural image. Part I. *Proceedings of the National Academy of Sciences of the USA, 45*(1), 115–129.

Land, E. H. (1959b). Color vision and the natural image. Part II. *Proceedings of the National Academy of Sciences of the USA, 45*(4), 636–644.

Land, E. H. (1959c). Experiments in color vision. *Scientific American, 200*(5), 84–96.

Land, E. H., & Daw, N. W. (1962). Binocular combination of projected images. *Science, 138*(3540), 589–590.

Lee, S.-M., Lee, K.-T., Lee, S.-H., & Song, J.-K. (2013). Origin of human colour preference for food. *Journal of Food Engineering, 119*, 508–515.

Lyman, B. (1989). *A psychology of food, more than a matter of taste*. New York: AVI, van Nostrand Reinhold.

Madden, T. J., Hewett, K., & Roth, M. S. (2000). Managing images in different cultures: A cross-national study of color meanings and preferences. *Journal of International Marketing, 8*(4), 90–107.

Meléndez-Martínez, A. J., Vicario, I. M., & Heredia, F. J. (2005). Correlation between visual and instrumental colour measurements of orange juice dilutions: Effect of the background. *Food Quality and Preference, 16*(5), 471–478.

Ngo, M. K., Piqueras-Fiszman, B., & Spence, C. (2012). On the colour and shape of still and sparkling water: Insights from online and laboratory-based testing. *Food Quality and Preference, 24*(2), 260–268.

O'Conner, Z. (2010). Colour harmony revisited. *Color Research & Application, 35*(4), 267–273.

Ou, L.-C., & Luo, M. R. (2006). A colour harmony model for two-colour combinations. *Color Research & Application, 29*, 191–204.

Piqueras-Fiszman, B., Alcaide, J., Roura, E., & Spence, C. (2012). Is it the plate or is it the food? Assessing the influence of the color (black or white) and shape of the plate on the perception of the food placed on it. *Food Quality and Preference, 24*(1), 205–208.

Piqueras-Fiszman, B., Giboreau, A., & Spence, C. (2013). Assessing the influence of the color of the plate on the perception of a complex food in a restaurant setting. *Flavour, 2*(1), 1–11. http://dx.doi.org/10.1186/2044-7248-2-24.

Piqueras-Fiszman, B., Velasco, C., & Spence, C. (2012). Exploring implicit and explicit crossmodal colour–flavour correspondences in product packaging. *Food Quality and Preference, 25*(2), 148–155.

Reutner, L., Genschow, O., & Wänke, M. (2015). The adaptive eater: Perceived healthiness moderates the effect of the color red on consumption. *Food Quality and Preference, 44*, 172–178.

Roullet, B., & Droulers, O. (2005). Pharmaceutical packaging color and drug expectancy. *Advances in Consumer Research, 32*, 164–171.

Schloss, K. B., & Palmer, S. E. (2011). Aesthetic response to color combinations: Preference, harmony, and similarity. *Attention, Perception & Psychophysics, 73*, 551–571.

Spence, C., & Piqueras-Fiszman, B. (2014). *The perfect meal: The multisensory science of food and dining*. Chichester, UK: Wiley.

Stevens, J. P. (2002). *Applied multivariate statistics for the social sciences* (4th ed.). Mahwah, NJ: Erlbaum.

Stockman, A., & Brainard, D. H. (2009). Color vision mechanisms. In M. Bass, C. DeCusatis, J. Enoch, V. Lakshminarayanan, G. Li, C. Macdonald, V. Maharajan, & E. van Stryland (Eds.), *The Optical Society of America Handbook of Optics, 3rd edition, Volume III: Vision and vision optics*. New York: McGraw-Hill.

Troost, J. M. (1998). Empirical studies in color constancy. In V. Walsh & J. Kulikowski (Eds.), *Perceptual constancy: Why things look as they do* (pp. 262–282). Cambridge, UK: Cambridge University Press.

Valdez, P., & Mehrabian, A. (1994). Effects of color on emotion. *Journal of Experimental Psychology: General, 123*, 394–409.

Velasco, C., Wan, X., Salgado-Montejo, A., Woods, A., Oñate, G. A., Mu, B., & Spence, C. (2014). The context of colour–flavour associations in crisps packaging: A cross-cultural study comparing Chinese, Colombian, and British consumers. *Food Quality and Preference, 38*, 49–57.

Wei, S.-T., Ou, L.-C., Ronnier Luo, M., & Hutchings, J. (2015). Psychophysical models of consumer expectations and colour harmony in the context of juice packaging. *Color Research & Application, 40*(2), 157–168. http://dx.doi.org/10.1002/col.21867.

Whitfield, T. W. A., & Wiltshire, T. J. (1990). Color psychology: A critical review. *Genetic, Social, and General Psychology Monographs, 116*(4), 387–411.

Wicaksono, S. H., Fu, T.-H., Chen, L.-Y., Hou, C.-Y., & Ou, L.-C. (2014). *Colour harmony of two colour combinations in clothes matching*. Paper presented at the international seminar on photonics, optics, and its applications, Sanur, Bali, Indonesia.