

RUNNING HEAD: COLOUR AND NUTRIENT

Colour-nutrient associations:

Implications for product design of dietary supplements

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24 **ABSTRACT**

25 Dietary supplements are prevalent and represent a huge (and still growing) global
26 market. Such products are intended to enhance health and wellness as well as to
27 supplement diets. Compared to the large amount of dietary supplements research on
28 nutrition, dietetics, and medicine, far less research has been conducted in the realm of
29 sensory and consumer science. Product design is undoubtedly an important element of
30 any brand's success, no matter what the category, and can be used to convey various
31 symbolic meanings to the consumer. Drawing on research on colour psychology and
32 product design, the present research aimed to clarify the associations (or expectations)
33 that consumers have with the particular product design of dietary supplements. Across
34 four studies, two of which were pre-registered, participants were asked to choose a
35 colour that they felt best matched each of the named nutrients. The results consistently
36 demonstrate that people associate nutrients with particular colours (i.e., colour patches;
37 Study 1) and to capsule/container colour; Studies 2-4). Vitamins supplements in
38 general, as well as vitamins C and D, in particular, were frequently matched with the
39 colours yellow and orange. Dietary fiber supplement was often matched with green.
40 Although mineral supplements were frequently matched with blue, each kind of mineral
41 appeared to have its own unique association with specific colours (magnesium/iron with
42 gray, calcium with white). Protein supplements (protein, amino acid) are frequently
43 matched with the colours orange and red. Taken together, these findings demonstrate
44 how people associate nutrients with specific visual design features and thus contribute
45 practical knowledge concerning the design of dietary supplements.

46

47 **Practical Applications**

48 Our findings provide practical implications for effective communication strategies
49 for nutrition with the consumer. Colour is one of important design elements, and it can
50 be true for the design of nutritional supplements and their packaging. Designers and
51 marketers can use our findings to help create better visual designs for dietary
52 supplements and their packaging to help meet consumers' expectations. Moreover, our
53 findings might also be fruitfully applied to marketing communications for functional
54 foods (e.g., vitamin-enriched foods, mineral-enriched foods). Marketers can presumably

55 capitalize on our findings of the colour-nutrition associations to effectively promote
56 functional foods.

57 *Keywords:* Dietary supplements; Colour; Hue; Fat; Protein; Mineral; Dietary Fiber;
58 Product Design

59

60 **HIGHLIGHTS**

- 61 • Colour-nutrient associations investigated in the context of dietary supplements.
- 62 • Vitamin supplements frequently matched with yellow and orange.
- 63 • Dietary fiber supplement frequently matched with green.
- 64 • Mineral supplements frequently matched with blue.
- 65 • Protein supplements frequently matched with orange and red.

66

Introduction

Dietary supplements

Dietary supplements are prevalent and constitute a huge global market. Such products are intended to enhance health and wellness as well as supplement diets (Dickinson et al., 2014). Such supplements are taken orally as the form of capsules, pills, tablets, powders, and/or liquids. There is a wide variety of dietary supplements on the market, including those that happen to be enriched with specific nutrients (e.g., protein, minerals, vitamins, dietary fiber) or supplements for weight loss (Hua et al., 2021; Pillitteri et al., 2008). The widespread availability of dietary supplements has been noted in the US (Radimer et al., 2004), Japan (Kobayashi et al., 2018), and various European countries (Skeie et al., 2009), amongst others. According to the results of one survey, approximately half of all adults in the United States had consumed dietary supplements within the preceding 30 days (Bailey et al., 2013). The global market for dietary supplements is huge and is predicted to reach USD 505.4 billion by 2028 (Globe Newswire, 2021).

Given the widespread prevalence of dietary supplements, a lot of research has been conducted in the realm of nutrition, dietetics, and medicine (Bailey et al., 2011; Dickinson & MacKay, 2014; Knapik et al., 2016). For example, previous research has investigated the demographic characteristics of dietary supplement use (Bailey et al., 2012) and the use of supplements on cognitive functions in the elderly (D'Cunha et al., 2018). However, to date, the consumer's inferences concerning dietary supplements have rarely been assessed experimentally (Bharadwaj & Bezborah, 2021; Pajor et al., 2017).

Consumer research has also been conducted in the domain of dietary supplements (Dickinson et al., 2015; Greger, 2001; Wu et al., 2012), though research is relatively scarce. The majority of the research that has been published to date has focused on demographic, socio-cognitive, and psychological determinants of dietary supplement use (Pajor et al., 2017). For example, dietary supplement use is higher in older (as compared to younger) adults (Dickinson et al., 2014), in women (vs. men; Dickinson et al., 2014), and more (vs. less) highly educated individuals (Jasti et al., 2003; Satia-Abouta et al., 2003). Individuals with positive attitudes (Pajor et al., 2017), higher subjective norms (Conner et al., 2001, 2003), higher perceived behavioral control (Chung et al., 2012; Conner et al., 2003), and higher health values as well as those who

are susceptible to illness (Conner et al., 2001) tend to be more inclined to the use of dietary supplements.

The present study was designed to investigate the associations (or expectations) that people have with the particular product design of dietary supplements (i.e., colour of capsules and containers). Product design is important for a brand's success in the marketplace and can be used to convey symbolic meanings to consumers (Bloch, 1995; Homburg et al., 2015). Consumer expectations are influenced by product-extrinsic factors such as product (and package) design (see Spence, 2021, for a review). Appropriately setting consumers' product expectations through effective product/packaging design is likely to increase fluency and positive evaluations (Piqueras-Fiszman & Spence, 2015; Spence, 2021). A few studies have revealed the role of design elements of dietary supplements on consumer evaluations (Delivett et al., 2020; Fiszman et al., 2015). For instance, placing health benefit-related images on the front-of-pack has been shown to increase the attractiveness of dietary supplements (Fiszman et al., 2015) as well as the perceived health benefits of the product (Delivett et al., 2020). However, to the best of our knowledge, no study has yet investigated the response of consumers to the sensory elements of the product design of dietary supplements. As such, it is currently unknown how consumers associate visual design elements such as colour with certain dietary supplements (e.g., vitamins, minerals).

Nutrient-based associations

Nutrient-based associations appear to be unique and different from taste-based associations in some cases. Although tastes are expected to represent specific nutrients, taste-nutrients associations are potentially more complex (Schiffman, & Dackis, 1975; van Dongen et al., 2012). On the one side, there are expected associations between tastes and nutrients. For example, sweet, salty and umami tastes signal carbohydrates, sodium, and proteins, respectively (see van Dongen et al., 2012). Actually, one study found that both savory and salty foods tend to have high sodium and protein content (van Dongen et al., 2012). On the other hand, there are no clear associations between some tastes and nutrients. Most vitamins and minerals have no apparent association with a specific taste (see van Dongen et al., 2012). One classical study suggests that nutrients are grouped due to olfactory and/or tactile factors rather than tastes (Schiffman, & Dackis, 1975). Moreover, van Donge and colleagues did not reveal clear

associations between nutrient contents and bitter and sour tastes (van Dongen et al., 2012). Together, the evidence suggests the unique nature of nutrient-based associations. Although colour-taste associations have been reported (e.g., Spence & Levitan, 2022), colour-nutrients associations appear to be different from them.

Nutrient-colour associations

Nutrients are closely linked to colours in consumer settings (e.g., Dréano-Trécant et al., 2020; Kunz et al., 2020). Previous research has been conducted in the domain of front-of-pack nutrition labels where colours have a clearly defined evaluative meaning (e.g., Dréano-Trécant et al., 2020; Kunz et al., 2020). For instance, colours are used in front-of-pack nutrition labels to suggest the healthfulness of foods (Dréano-Trécant et al., 2020; Kunz et al., 2020). The traffic light labeling tells consumers whether a food is high (red), middle (amber), or low (green) in one of four nutrients (fat, sugar, saturates, and salt; Thorndike et al., 2019). Nutri-score also indicates the five levels (from A to E) of nutrients by colour. Green colour indicates “A” score and red colour represents “E” score. It appears that these front-of-pack nutrition labels were developed on the basis of the intuition that consumers would associate green with healthy and red with unhealthy. However, it has been largely unknown how consumers associate specific nutrients (e.g., fat, sugar, and salt) with colours. When it comes to specific nutrients (e.g., fat, sugar, and salt) and supplementary diets of nutrients, the colours of supplementary diets of nutrients do not have a clearly defined evaluative meaning. Do consumers consistently associate specific classes of nutrients with colours? The present research was specifically designed to investigate this issue.

Some research has investigated the associations between nutrition, healthfulness, and colour, though the number of studies is still relatively limited (Huang & Lu, 2016; Schuldt, 2013; Tijssen et al., 2017; Wąsowicz et al., 2015). Most of the research has focused on the nature of any associations between colour and perceived healthfulness (Huang & Lu, 2016; Schuldt, 2013; Wąsowicz et al., 2015). For example, one study reported by Schuldt revealed that green nutrition labels were perceived as healthier than red or white labels. However, the amount of research on the associations between nutrition and colour is limited. As one exception, Tijssen and her colleagues reported that people expected a sausage product that was presented in red packaging to be higher

in fat than the same product when presented in blue and green packaging instead (Tijssen et al., 2017).

The present research

This study was designed to investigate the associations between nutrition and colour in the context of dietary supplements. Across four studies, two of which were pre-registered, participants were asked to choose one of 11 colours (red, black, blue, brown, gray, green, orange, pink, purple, white, and yellow; Wan et al., 2014) that they felt best matched each of the nutrients (fat, carbohydrate, protein, minerals, vitamins, and dietary fiber). Study 1 tested for simple associations between nutrition and colour. Studies 2-4 were conducted in the context of dietary supplements, and different design elements were used to expand the generalizability of our findings. Study 2 examined how people associate the colour of capsules with components of dietary supplements. Study 3 investigated whether people associate the colour of containers with components of dietary supplements. Study 4 used more diverse nutrients and subcomponents thereof (magnesium, iron, calcium, vitamin D, vitamin C, omega-3 fatty acids, and amino acid) in the context of capsule colour.

Methods

Participants

In Study 1, a total of 102 Japanese participated in an online survey in exchange for a small monetary compensation. All of the data were used for analyses (61 males, 37 females, 4 prefer not to say, mean age of 40.44 years, SD = 9.88). In Study 2, a total of 100 Japanese participants took part in an online survey. All of the data were used for analyses (62 males, 35 females, 3 prefer not to say, mean age of 42.27 years, SD = 8.56). In Study 3, data collection was opened in order to recruit 100 participants and a total of 101 Japanese participants took part in the online survey. All of the data were used for analyses (48 males, 52 females, 1 prefer not to say, mean age of 42.82 years, SD = 9.63). In Study 4, we opened data collection to recruit 100 participants and a total of 100 Japanese participants took part in an online survey. All of the data were used for analyses (50 males, 50 females, mean age of 43.39, SD = 8.79). In all studies, the participants in this and the following studies were recruited on Lancers

(<https://lancers.jp/>) and they completed a survey on Qualtrics (<https://www.qualtrics.com/jp/>) in exchange for a small monetary reward. The sample size was determined based on the relevant previous research and the assumption of the likely effect size (e.g., Chen et al., 2021 for an example of colour-taste correspondences). We estimated that a sample size of 98 for each study would be sufficient to detect an effect size ($w = 0.50$) with 95% power at $\alpha = 0.05$ (see Faul et al., 2007). Based on this calculation, the data of about 100 participants was collected for each study. All of the studies described herein were approved by the ethics committee of Miyagi University and were conducted in accordance with the Declaration of Helsinki. The data, stimuli, and code are available at https://osf.io/5tg6a/?view_only=6a9c22099e174dbbbd4a88db140950c5.

Procedures

In all studies, the participants were asked to choose one of eleven colours (red, black, blue, brown, gray, green, orange, pink, purple, white, and yellow) that they felt best matched each of the nutrients. We chose the eleven colours based on previous research on colour-taste correspondences to cover a variety of hues (Wan et al., 2014). The eleven colours have been also considered as “basic colours” (Sturges & Whitfield, 1995). To increase the generalizability of our findings, the colours were manipulated in a different manner across studies (Study 1: colour patch; Studies 2 and 4: colour of supplement capsules; Study 3: colour of supplement container).

Six nutrients (fat, carbohydrate, protein, minerals, vitamins, and dietary fiber) were used in Study 1. They included major nutrients (fat, carbohydrate, protein, minerals, vitamins). We also chose dietary fiber because the supplement was common especially in Japan where the study was conducted. Studies 2-3 also used six nutrients (suppressing the absorption of fat, suppressing the absorption of carbohydrate, vitamin, mineral, dietary fiber, and protein). Two nutrients (fat, carbohydrate) were replaced with versions of suppressing absorption (suppressing the absorption of fat, suppressing the absorption of carbohydrate) because those supplements that enhance fat/carbohydrates appear to be rare. For completeness, Study 4 used more diverse range of nutrients and their subcomponents (magnesium, iron, calcium, vitamin D, vitamin C, omega-3 fatty acids, and amino acid). The additional nutrients were selected because there are commonly used as dietary supplements (see Dickinson et al., 2014). The order

in which the nutrients and colours were presented was randomized on a trial-by-trial basis.

Statistical analyses

Chi-square tests were conducted to test whether certain colours were chosen more frequently than the others for particular nutrients. The adjusted residual analyses were used to test which colours were significantly associated with a given nutrient. We focus on the only positive residuals (i.e., the degree of more frequently chosen than expected) as in previous research (e.g., Chen et al., 2021). The false discovery rate (FDR) was applied to adjust for multiple testing (Benjamini & Hochberg, 1995).

Study 1: Colour of nutrients

Study 1 investigate how people associate nutrients (fat, sugar, protein, minerals, vitamins, and dietary fiber) with colour (red, black, blue, brown, gray, green, orange, pink, purple, white, and yellow). The colours were presented as colour patches and created based on the following HTML colour codes: Red (#ff0000), Pink (#ffb6c1), Brown (#a52a2a), Orange (#ffa500), Yellow (#ffff00), Green (#008000), Blue (#0000ff), Purple (#800080), White (#ffffff), Gray (#808080), and Black (#000000).

Results

Chi-square analysis showed significant associations of colour with fat ($\chi^2_{10} = 61.49$, $p < .001$, Cramer's $V = 0.246$), sugar ($\chi^2_{10} = 328.08$, $p < .001$, Cramer's $V = 0.567$), proteins ($\chi^2_{10} = 69.255$, $p < .001$, Cramer's $V = 0.261$), minerals ($\chi^2_{10} = 358.49$, $p < .001$, Cramer's $V = 0.593$), vitamins ($\chi^2_{10} = 419.75$, $p < .001$, Cramer's $V = 0.642$), and dietary fiber ($\chi^2_{10} = 419.96$, $p < .001$, Cramer's $V = 0.642$).

Fat was frequently associated with yellow (20.59%, $z = 4.04$, $\text{adj.}p = .001$) and orange (20.59%, $z = 2.32$, $\text{adj.}p = .038$). Sugar was frequently associated with white (58.82%, $z = 17.47$, $\text{adj.}p < .001$). Protein was frequently associated with red (25.53%, $z = 5.07$, $\text{adj.}p < .001$), orange (18.63%, $z = 3.35$, $\text{adj.}p = .004$), and brown (15.69%, $z = 2.32$, $\text{adj.}p = .032$). Minerals were frequently associated with blue (63/102, 61.76%, $z =$

18.50, $\text{adj.p} < .001$). Vitamins were frequently associated with yellow (64.71%, $z = 19.54$, $\text{adj.p} < .001$) and orange (17.65%, $z = 3.01$, $\text{adj.p} = .004$). Dietary fiber was frequently associated with green (66.76%, $z = 20.23$, $\text{adj.p} < .001$). The detailed results are presented in the Supplementary materials.

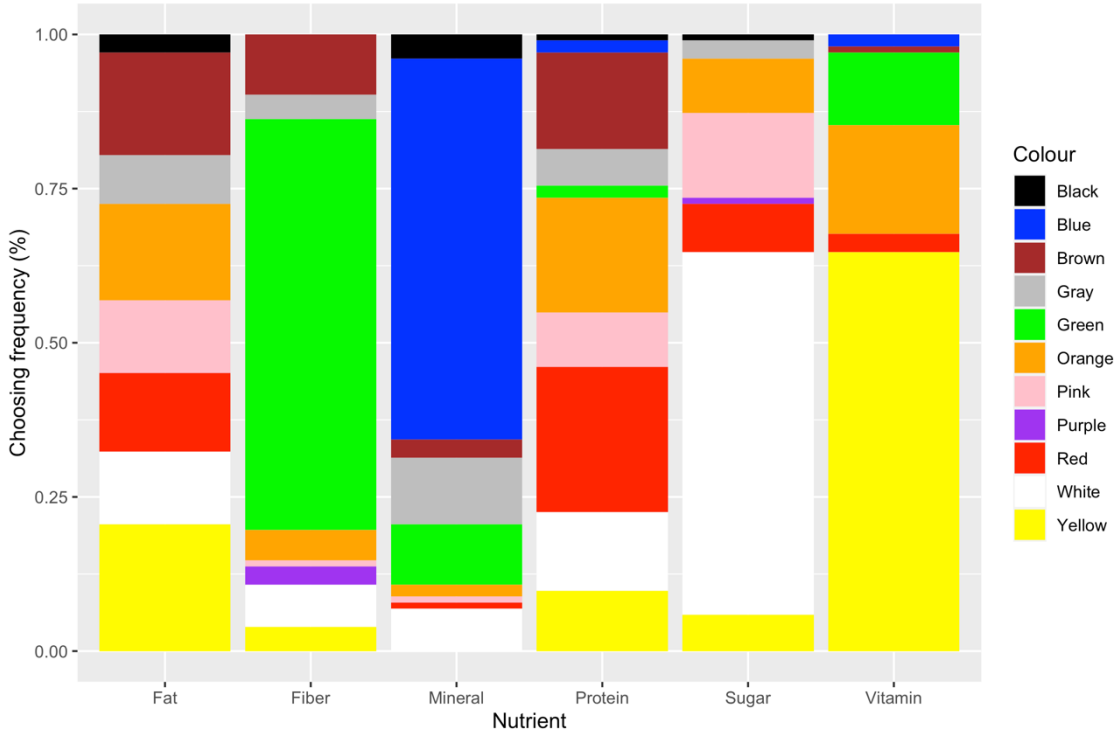


Figure 1. Frequency of colour choices for each nutrient in Study 1.

Discussion

The results of Study 1 revealed that participants non-randomly associated specific nutrients with colours. Fat was frequently associated with yellow and orange; sugar with white; protein with red, orange and, brown; minerals with blue; vitamins with yellow and orange; dietary fiber with green. The findings suggest that each nutrient is uniquely associated with different colours.

Study 2: Colour of supplement capsules

Study 2 investigate how people associate capsules of dietary supplement (suppressing fat absorption, suppressing carbohydrate absorption, protein, minerals, vitamins, and dietary fiber) with colour. The coloured supplement capsule stimuli were created by a designer and are displayed in Figure 2. Most of capsules two different tones or colours in one capsule (Bhuyan, 2016). Given this, to increase the ecological validity, our stimuli of coloured supplement capsules consists of different shading but same hue category (see Figure 2). We use suppressing fat/carbohydrate absorption. In the case of fat and carbohydrates, the supplements of blocking their absorption are common dietary supplements in the marketplace (e.g., Saper et al., 2014).



Figure 2. The coloured dietary supplement capsules used in Studies 2 and 4. The stimuli composed of colour pairs (different shading but same hue category; see Woods, Marmolejo-Ramos, Velasco, & Spence, 2016; Woods & Spence, 2016).

Results

The results of chi-square analyses showed significant associations of colour with the suppression of fat absorption ($\chi^2_{10} = 56.86, p < .001$, Cramer's $V = 0.239$), the suppression of carbohydrate absorption ($\chi^2_{10} = 70.28, p < .001$, Cramer's $V = 0.265$), proteins ($\chi^2_{10} = 50.04, p < .001$, Cramer's $V = 0.224$), minerals ($\chi^2_{10} = 139.58, p < .001$, Cramer's $V = 0.374$), vitamins ($\chi^2_{10} = 314.7, p < .001$, Cramer's $V = 0.561$), and dietary fiber ($\chi^2_{10} = 375.86, p < .001$, Cramer's $V = 0.613$).

The suppression of fat absorption function was frequently associated with the colours pink (24.0%, $z = 5.19$, $\text{adj.p} < .001$) and white (20.0%, $z = 3.80$, $\text{adj.p} < .001$). The suppression of carbohydrate absorption function was frequently associated with the colours white (29.0%, $z = 6.93$, $\text{adj.p} < .001$) and pink (19.0%, $z = 3.45$, $\text{adj.p} = .003$). Protein was frequently associated with orange (21.0%, $z = 4.14$, $\text{adj.p} < .001$) and white (19.0%, $z = 3.45$, $\text{adj.p} = .003$). The mineral category was frequently associated with blue (39.0%, $z = 10.40$, $\text{adj.p} < .001$), while the vitamin category was frequently associated with yellow (47.0%, $z = 13.19$, $\text{adj.p} < .001$) and orange (39.0%, $z = 10.40$, $\text{adj.p} < .001$). Dietary fiber was frequently associated with green (64.0%, $z = 19.10$, $\text{adj.p} < .001$). The details of the results are shown in Supplementary materials.

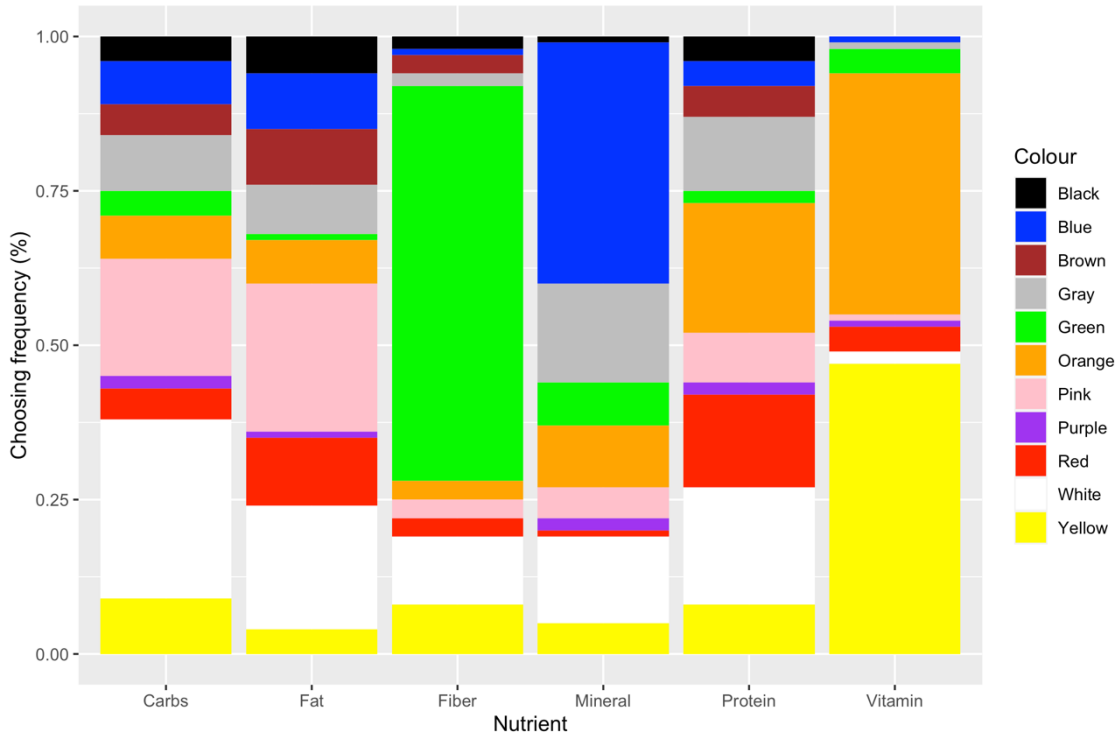


Figure 3. Frequency of colour choices for each nutrient in Study 2. Fat and carbs indicate the suppression of fat absorption and the suppression of carbohydrate absorption functions, respectively.

Discussion

The results of Study 2 demonstrated that participants non-randomly associated dietary supplements of specific nutrients with coloured capsules. The suppression of fat absorption function was frequently associated with pink and white; the suppression of carbohydrate absorption function with white and pink; protein with orange and white; mineral with blue; vitamin with yellow and orange; dietary fiber with green. The results of Studies 1 and 2 suggest that some of nutrient-colour associations (i.e., mineral-blue, vitamin-yellow/orange, fiber-green) appear to be reliable and consistently found in both colour patch and coloured capsules.

Study 3: Colour of supplement container

To test whether these findings (colour-supplement correspondences) can be generalized into the other type of stimuli, Study 3 investigate how people associate the colour of container lids with the various components found in dietary supplements. The stimuli of Study 2 consist of different shading but same hue category. Instead, Study 3 used a single colour. The colour and dietary supplements were the same as those used in Study 2. The coloured supplement capsule stimuli were created by a designer and shown in Figure 2.

Methods

Procedures and analyses

Participants were asked to choose a supplement container (from 11 colours) that best matches each of the dietary supplements (the suppression of fat absorption, the suppression of carbohydrate absorption, vitamin, mineral, dietary fiber, and protein). The study was pre-registered at https://aspredicted.org/TBN_KMD.



Figure 4. The stimuli of dietary supplement containers used in Study 3.

Results

The results of chi-square analyses showed significant associations of colour with proteins ($\chi^2_{10} = 50.713$, $p < .001$, Cramer's $V = 0.224$), minerals ($\chi^2_{10} = 52.455$, $p < .001$, Cramer's $V = 0.228$), and vitamins ($\chi^2_{10} = 261.13$, $p < .001$, Cramer's $V = 0.509$), dietary fiber ($\chi^2_{10} = 353.49$, $p < .001$, Cramer's $V = 0.592$). The analyses did not obtain significant findings (i.e., colour associations for the suppression of fat absorption ($\chi^2_{10} = 13.465$, $p = .199$, Cramer's $V = 0.112$) and for the suppression of carbohydrate absorption ($\chi^2_{10} = 17.822$, $p = .058$, Cramer's $V = 0.133$).

Protein was frequently associated with the red lids (24.75%, $z = 5.48$, $\text{adj.p} < .001$). The mineral was frequently associated with the blue (24.75%, $z = 5.48$, $\text{adj.p} < .001$) and gray container lids (17.82%, $z = 3.05$, $\text{adj.p} = .013$). Vitamin was frequently associated with the yellow (43.56%, $z = 12.05$, $\text{adj.p} < .001$) and orange lid colours (35.64%, $z = 9.28$, $\text{adj.p} < .001$). Dietary fiber was frequently associated with green the lid (62.38%, $z = 18.63$, $\text{adj.p} < .001$). The details of the results are shown in Supplementary materials.

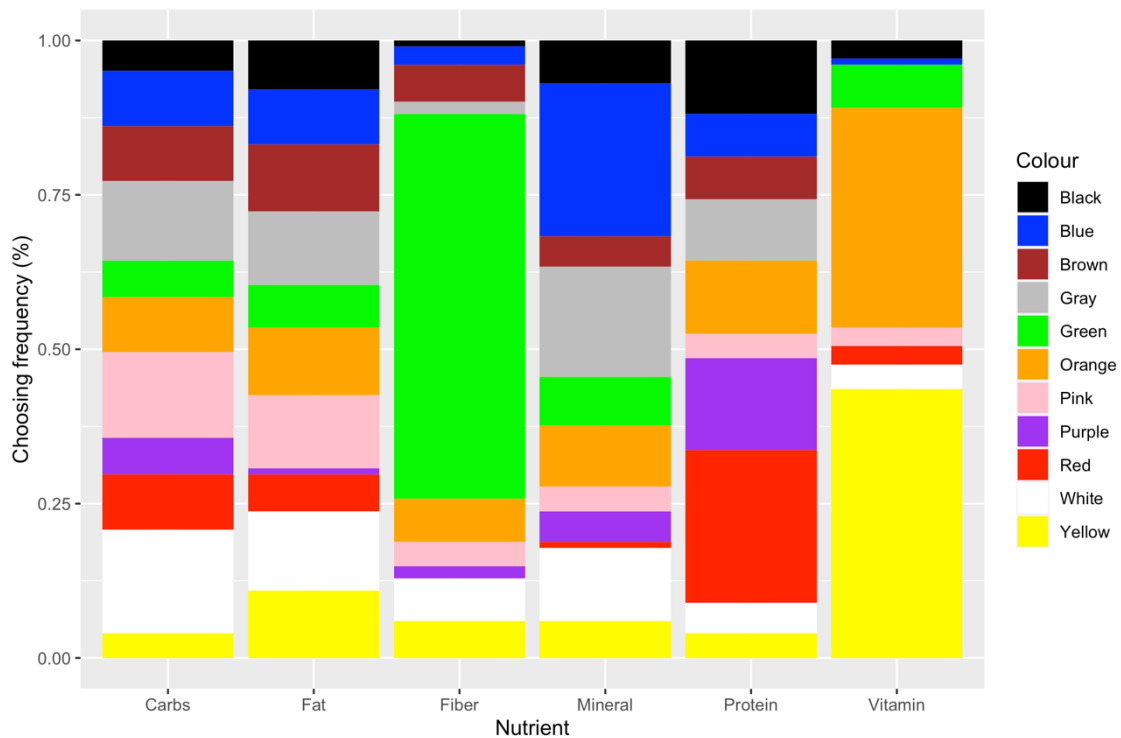


Figure 5. Frequency of colour choices for each nutrient in Study 3. Fat and carbs indicate suppressing fat absorption and suppressing carbohydrates absorption, respectively.

Discussion

The results of Study 3 demonstrated that participants associated dietary supplements of specific nutrients with coloured lids of containers in a non-random manner. Protein was frequently associated with the red lids; mineral with the blue and gray; vitamin with the yellow and orange; dietary fiber with green. The findings indicate that three of nutrient-colour associations (i.e., mineral-blue, vitamin-yellow/orange, fiber-green) are observed regardless of the type of colored design elements and are robust. Other nutrient-colour associations might, however, be specific for design elements.

Study 4: Colour of supplement capsule

To expand our findings, Study 4 used a more diverse array of nutrients and their subcomponents (magnesium, iron, calcium, vitamin D, vitamin C, omega-3 fatty acids, and amino acid) in the context of coloured capsules.

Procedures and analyses

The participants were asked to choose a supplement capsule (from 11 colours; see Figure 2) that best matched each category of dietary supplement (magnesium, iron, calcium, vitamin D, vitamin C, omega-3 fatty acids, and amino acid). The study was pre-registered at https://aspredicted.org/3LQ_8M1.

Results

Chi-square analysis showed significant associations of colour with magnesium ($\chi^2_{10} = 160.48, p < .001$, Cramer's $V = 0.401$), iron ($\chi^2_{10} = 133.2, p < .001$, Cramer's $V = 0.365$), calcium ($\chi^2_{10} = 628.64, p < .001$, Cramer's $V = 0.793$), vitamin D ($\chi^2_{10} = 175.22, p < .001$, Cramer's $V = 0.419$), vitamin C ($\chi^2_{10} = 572.32, p < .001$, Cramer's $V = 0.757$), omega-3 fatty acids ($\chi^2_{10} = 40.36, p < .001$, Cramer's $V = 0.201$), and amino acid ($\chi^2_{10} = 43.44, p < .001$, Cramer's $V = 0.208$).

Magnesium was frequently associated with gray (40.0%, $z = 10.75$, adj. $p < .001$), white (20.0%, $z = 3.79$, adj. $p < .001$), and black capsules (16.0%, $z = 2.40$, adj. $p = .025$). Iron was frequently associated with gray (32.0%, $z = 7.97$, adj. $p < .001$), brown (23.0%, $z = 4.84$, adj. $p < .001$) and black capsules (21.0%, $z = 4.14$, adj. $p < .001$). Calcium was frequently associated with white capsules (81.0%, $z = 25.01$, adj. $p < .001$). Vitamin D was frequently associated with orange capsules (46.0%, $z = 12.84$, adj. $p < .001$). Vitamin C was frequently associated with yellow (47.0%, $z = 23.27$, adj. $p < .001$) and orange capsules (18.0%, $z = 3.10$, adj. $p = .003$). Omega-3 fatty acids were frequently associated with blue capsules (24.0%, $z = 5.19$, adj. $p < .001$). Amino acids were frequently associated with red (20.0%, $z = 3.79$, adj. $p = .001$) and orange capsules (19.0%, $z = 3.45$, adj. $p = .003$). The detailed results can be found in the Supplementary materials.

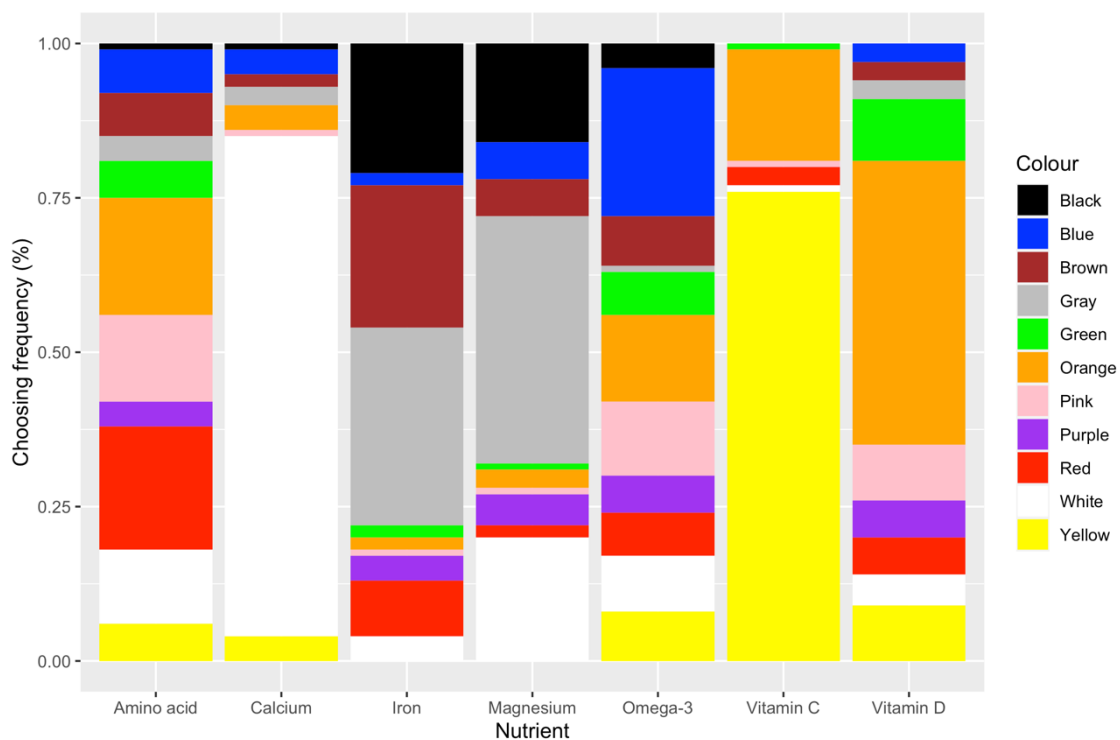


Figure 6. Frequency of colour choices for each category of nutrient in Study 4.

Discussion

The results of Study 4 demonstrated that participants non-randomly associated dietary supplements of specific nutrients with coloured capsules. Magnesium was frequently associated with gray and black capsules; iron with gray, brown, and black capsules; calcium with white; vitamin D with orange; vitamin C with yellow and orange; omega-3 fatty acids with blue; amino acids with red and orange. The findings revealed the nuanced associations of nutrients and colours. The subcomponents of a nutrient show different associations with colours. For example, both magnesium and iron are categorized as mineral but they are associated with similar but distinct colours (magnesium-gray/black, iron-gray/brown/black).

Table 1. Summary of findings: Nutrient and colour associations in Studies 1-4.

Study 1	- <u>Fat</u> : Yellow (20.6%), Orange (15.7%)
(Colour patch)	- <u>Sugar</u> : White (50.8%)

	<ul style="list-style-type: none"> - <u>Protein</u>: Red (25.5%), Orange (18.6%), Brown (15.7%) - <u>Mineral</u>: Blue (69.8%) - <u>Vitamin</u>: Yellow (64.7%), Orange (17.7%) - <u>Dietary fiber</u>: Green (66.7%)
Study 2 (Supplement capsules)	<ul style="list-style-type: none"> - <u>Suppressing fat absorption</u>: Pink (24.0%), White (20.0%) - <u>Suppressing carbohydrates absorption</u>: White (29.0%), Pink (19.0%) - <u>Protein</u>: Orange (21.0%), White (19.0%) - <u>Mineral</u>: Blue (39.0%), Gray (16.0%) - <u>Vitamin</u>: Yellow (47.0%), Orange (39.0%) - <u>Dietary fiber</u>: Green (64.0%)
Study 3 (Supplement container lids)	<ul style="list-style-type: none"> - <u>Suppressing fat absorption</u>: n/a. - <u>Suppressing carbohydrates absorption</u>: n/a. - <u>Protein</u>: Red (24.8%) - <u>Mineral</u>: Blue (24.8%), Gray (17.8%) - <u>Vitamin</u>: Yellow (43.6%), Orange (35.6%) - <u>Dietary fiber</u>: Green (62.4%)
Study 4 (Supplement capsules)	<ul style="list-style-type: none"> - <u>Magnesium</u>: Gray (40.0%), White (20.0%), Black (16.0%) - <u>Iron</u>: Gray (32.0%), Brown (23.0%), Black (21.0%) - <u>Calcium</u>: White (81.0%) - <u>Vitamin C</u>: Yellow (76.0%), Orange (18.0%) - <u>Vitamin D</u>: Orange (46.0%) - <u>Omega-3 fatty acids</u>: Blue (24.0%) - <u>Amino acid</u>: Red (20.0%), Orange (19.0%)

Note: Significant nutrient-colour association shown (FDR adjusted p value < .05; Benjamini & Hochberg, 1995).

General Discussion

Summary of findings

The aim of the present study was to investigate the associations between nutrients and colour in the context of dietary supplements. Across four studies, two of which were pre-registered), the participants had to choose the colour that they felt best matched each of the nutrients. simple associations between nutrients and abstract colour patches were tested in Study 1. Studies 2 and 4 examined how people associate the

colour of capsules with components of dietary supplements. Study 3 investigated how people associate the colour of container lids with components of dietary supplements. The results demonstrate that people associate nutrients with particular colour(s). Some of the nutrients (i.e., vitamin, fiber, mineral) are reliably and consistently associated with specific colours across Studies 1 and 3. Specifically, the vitamin is frequently associated with yellow and orange. Dietary fiber is frequently matched with the colour green. The mineral category is frequently matched with the colour blue. Moreover, the results of Study 4 reveal the nuanced association of nutrient and colour, and, say, each kind of mineral has its own unique pattern of association with specific colours (e.g., magnesium/iron with gray, calcium with white). These findings demonstrate how people associate nutrition with specific colour cues and contribute practical applications of dietary supplements design.

Contributing to colour association with food-related factors

The results of the four experiments reported here contribute to a better understanding of colour associations with food-related factors. Previous research has investigated the relations between colour and taste/flavor (Spence, 2019; Spence et al., 2015). Specifically, crossmodal correspondences research has revealed that people tend to significantly match particular basic tastes with specific colours (Chen et al., 2021; Motoki, Takahashi, et al., 2021; Spence, 2019; Spence et al., 2015; Spence & Levitan, 2021, 2022). For example, pink is associated with sweetness, yellow with sourness, black with bitterness (Chen et al., 2021; Motoki, Takahashi, et al., 2021; Spence, 2019; Spence et al., 2015; Spence & Levitan, 2021, 2022). However, the associations of colour with other food-related factors have not been so extensively studied to date. Our findings help to start fill this gap in the experimental literature and reveal that people tend to match nutrients with colours in a way that is somewhat predictable.

Our findings suggest that product/packaging designers might be well advised to use distinctive strategies (or cognitive process) for taste-colour and nutrient-colour correspondences. It has been suggested that taste perception have evolved in order to allow to detect nutritional value (e.g., Temussi, 2009). For example, sweet and umami tastes might serve as cues signalling sugar and protein, respectively (e.g., Keast, Costanzo, & Hartley, 2021; Temussi, 2009). Previous research on taste-colour correspondences found that umami is associated with the colour brown (e.g., Chen et al., 2021; see also Ikeda, 1909/2002). In contrast, our findings on nutrient-colour

correspondences show that protein is frequently associated with red and orange. Moreover, prior research has revealed that sweetness tends to be associated with a reddish colour, especially pink (e.g., Chen et al., 2021; Spence & Levitan, 2021, 2022). However, our findings demonstrate that sugar is frequently associated with white, though suppressing carbohydrates absorption is frequently matched with white as well as pink. Taken together, our results suggest that nutrient-colour correspondences may be different in kind from crossmodal correspondences involving basic tastes and the context-dependent nature of colour's association/priming function (see Elliot & Maier, 2012).

On the design of pharmaceuticals and their packaging

Our findings contribute to the existing body of research on the design of pharmaceuticals and their packaging (see Spence, 2021, for a review). Dietary supplements are taken for different reasons (e.g., to maintain a healthy heart) from pharmaceuticals (e.g., to prevent disease). But the form of dietary supplements is very similar to pharmaceuticals (e.g., capsules). Several studies have investigated the role of pharmaceutical pill colour on consumer expectations (e.g., taste, alertness, efficiency) (Naeve, 2010; Tao et al., 2017, 2018; Wan et al., 2015). For example, Wan and colleagues investigated the influence of pharmaceutical pill colour on expected taste, alertness, and efficiency (Wan et al., 2015). Their research revealed that people expected blue tablets to taste less bitter than either green or red tablets. Red tablets were expected to increase alertness more than green and blue tablets (Wan et al., 2015). However, the existing research has focused on the factors regarding (psychoactive) drugs (e.g., stimulant, analgesic, hallucinogenic, depressant; Tao et al., 2017, 2018). To the best of our knowledge, no published research has investigated the role of colour design of pharmaceuticals on nutritional expectancy. Our results reveal that each nutrient category is uniquely associated with one or more specific colours (from the 11 that were tested) and provide additional knowledge into the literatures of the design of pharmaceuticals and their packaging.

Psychological mechanisms

Why do participants associate colours with nutrients in a non-random manner? Multiple theoretical accounts appear capable of potentially explaining the existence of

colour-nutrient associations. One account is in terms of statistical, or associative, learning (Spence, 2021). That is, people might simply learn the statistical association between colours and nutrients. For example, product design, package design, and/ or marketing communications of supplements (e.g., vitamin) might preferentially use certain colours (e.g., yellow, orange) over others, and consumers might internalize the associations. **Actually, it has been suggested that colour-flavour associations have been learned through repeated exposure to a given product or brand in the marketplace (Piqueras-Fiszman, & Spence, 2011; Velasco et al., 2014). Similar explanations might be possible for the colour-nutrient associations.** Another account is in terms of the representativeness of the food source of nutrients. There might be representative foods for each of the nutrients. For example, when people think about vitamin C, “lemon”, “oranges” or “citrus fruits” might come to mind as a representative food source. **Similarly, green-dietary fiber associations appear to be come from the belief that green vegetables are high in fiber. White-sugar associations are also likely to be derived from the white appearance of sugar. Thus, people might judge the colour-nutrients association by relying on the colour of the representative foods that they can bring to mind (e.g., yellow for lemon; Spence & Levitan, 2022).**

A third account is in terms of emotional and/or semantic similarities. Colours and nutrients might have similar emotional and/or semantic meanings. For example, red/orange-protein associations might be partially explained by shared emotional meanings. Red/orange is associated with positive arousing emotions (Hanada, 2018) and protein might be also linked with positive arousing emotion. Green-dietary fiber associations appear to be partly derived from similar semantic meanings in terms of healthiness. Both green and dietary fiber are associated with healthiness (Meng & Chan, 2022; Rizk, & Treat, 2015). Pink-suppressing fat absorption associations might be partially explained by shared feminine associations. Pink is associated with feminine brands (Hess & Melnyk, 2016) and suppressing fat absorption might be recognized as products for females. It is important to note that these accounts are non-exclusive and each colour-nutrient association might be explained by different underlying mechanisms. Future research should therefore systematically examine similarity and differences of the underlying mechanisms of each colour-nutrient association. Given the possible cultural differences in dietary supplement colours that a dominant brand in the marketplace sell, it is also worth suggesting the benefits of conducting cross-cultural research

Practical implications

Our findings provide practical implications for effective communication strategies for nutrition. Specifically, our results can be used for the design of nutritional supplements/functional foods and their packaging (Spence, 2021). According to our findings, it appears to be better to design the colour of vitamin supplements and their packaging to present a yellow colour at least in Japan (see also Caivano & Lopez, 2017). It appears to be better than the colour of fiber supplements and their packaging should be designed in green colour. Moreover, our findings might also be fruitfully applied to marketing communications for functional foods (e.g., vitamin-enriched foods, mineral-enriched foods). Marketers can presumably capitalize on our findings of the colour-nutrition associations to effectively promote functional foods. For example, appealing messages, product colours, packaging colour, and advertising colour can be designed based on our findings of the colour-nutrition associations.

Our findings may have practical relevance concerning the optimization of the congruence between colours and specific nutrients. Previous research has shown that the congruence between senses increase attention, willing to pay, and/or valuation of consumers (e.g., de Sousa, Carvalho, & Pereira, 2020; Sunaga, Park, & Spence, 2016; Motoki et al., 2019). For example, congruent pair of colour and flavour (e.g., red and tomato flavour) facilitate visual search (Velasco et al., 2015) and enhance likability of the products (Huang & Wan, 2019) compared with the incongruent pair (e.g., green and tomato flavour). Given these findings, it would be predicted that the congruence between colour and nutrients (e.g., green coloured dietary fiber supplements) enhance consumers' visual search and preferences. The positive effects of congruence may potentially also help to address the very important problem of non-compliance of nutritional supplements (Lester et al., 2022 for a review). Taken together, appropriately designing colour of dietary supplements colour would be expected to enhance customer experiences, and practitioners can capitalize on the expected downstream consequences of the congruence between colour and nutrients. Further research should empirically test the predictions.

Limitations and future research

Our research especially focuses on colour hue, as most research of colour-taste correspondences (Spence & Levitan, 2021). However, colour also contains lightness

(Motoki et al., 2019) and saturation (Spence & Levitan, 2021). We did not control colour parameters of lightness/saturation of our stimuli, which might have influenced our findings. Although some studies did not reveal the matching of saturation with other sensory attributes (Motoki, Takahashi et al., 2021; Wicker, 1968), lightness is associated with sensory attributes such as tastes (Motoki, Takahashi et al., 2021). Further research therefore needs to investigate the relationship between other colour parameters (e.g., lightness, saturation) and nutrients. Moreover, the colour parameters of the stimuli might be expected to influence our findings. Although we tried to manipulate colour hue, the other colour parameters (lightness, saturation) of the stimuli might be also changed. It should be also noted that the background colour might influence our results. More research should be needed to replicate our findings by using more controlled-colour stimuli.

Second, cultural differences might well be expected to influence our findings. It has been suggested there are some cross-cultural differences in meanings of colour (e.g., Caivano & Lopez, 2017) and colour-taste correspondences (Wan et al., 2014). Dominant brand colour in marketplace (e.g., coloured package in a certain dietary supplement) might differ between cultures (cf. Baxter, Ilicic, & Kulczynski, 2018) and vary across ages (see Spence, 2021). Meanwhile, some studies suggest high degree of cross-cultural agreement in connotative meanings of colours (e.g., capsule colours) (Osgood, 1960; Tao et al., 2017; Wan et al., 2015). Future studies should therefore test whether our findings can be generalized to other cultures.

Third, it is an open question how other design elements (e.g., shapes, typefaces, sound symbolism of brand names, logos) (Mick, 1986; Motoki, Park, et al., 2021; Park et al., 2021; Velasco et al., 2018; Wan et al., 2014) are associated with nutrition/dietary supplements. Although previous research on crossmodal correspondences and/or multisensory design of pharmaceuticals treat with the other design elements (e.g., shapes, typefaces, sound symbolism of brand names, logos), the other design elements have been less applied to nutrition/dietary supplements. Fourth, the bi-directionality of colour-nutrient associations remain uninvestigated. In our studies, participants were asked to choose one of eleven colours that they felt best matched a given class of nutrient. However, the opposite was not investigated (i.e., asking participants to choose one nutrient that they feel best matched each of the colours). Given that colour-taste correspondences appear to be bi-directional (Spence et al., 2015), the same might also be true of colour-nutrient associations. Fourth, investigating the role of individual differences in nutrient-colour associations would be a future avenue. Variables

associated with nutrition and health such as nutritional knowledge, and health consciousness might modulate the degree of nutrient-colour associations. Fifth, it remains unknown how consumers evaluate artificial colored supplements. Previous research suggests that consumers may sometimes have negative evaluations of artificial food colours (Bearth, Cousin, & Siegrist, 2014). Even if the artificial colored supplements match the nutrients, consumers might prefer supplements with non-artificial colours.

Moreover, although many dietary supplements contain an individual nutrient, some include multiple nutrients (e.g., vitamin C and Calcium). The colour design of these supplements might be possible through certain combinations of colours (see Spence & Di Stefano, 2022). For example, the design of dietary supplements containing both vitamin C and Calcium appear to be well-matched with the combination of orange and white colours. However, future research will be needed in order to investigate this intriguing issue more thoroughly. Finally, nutrient-colour associations might be dependent on the type of product (i.e., dietary supplements, functional foods). Recent research has shown that functional foods that inhibit absorption of dietary fat is associated with greenish colour (Raevskiy, Bubnov, Chen, & Sakai, 2022). Meanwhile, our results show that suppressing fat absorption is linked with pink and white. Further research should examine the differences in detail.

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References

- Bailey, R. L., Fulgoni, V. L., 3rd, Keast, D. R., & Dwyer, J. T. (2011). Dietary supplement use. is associated with higher intakes of minerals from food sources. *The American Journal of Clinical Nutrition*, 94(5), 1376–1381.
- Bailey, R. L., Fulgoni, V. L., 3rd, Keast, D. R., & Dwyer, J. T. (2012). Examination of vitamin intakes among US adults by dietary supplement use. *Journal of the Academy of Nutrition and Dietetics*, 112(5), 657–663.
- Bailey, R. L., Gahche, J. J., Miller, P. E., Thomas, P. R., & Dwyer, J. T. (2013). Why US adults use dietary supplements. *JAMA Internal Medicine*, 173(5), 355–361.
- Baxter, S. M., Ilicic, J., & Kulczynski, A. (2018). Roses are red, violets are blue, sophisticated brands have a Tiffany hue: The effect of iconic brand colour priming on brand personality judgments. *Journal of Brand Management*, 25, 384–394.
- Bearth, A., Cousin, M.-E., & Siegrist, M. (2014). The consumer's perception of artificial food additives: Influences on acceptance, risk, and benefit perceptions. *Food Quality and Preference*, 38, 14–23.

642 Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and
643 powerful approach to multiple testing. *Journal of the Royal Statistical Society: Series B*,
644 57(1), 289–300.

645 Bharadwaj, S., & Bezborah, D. P. (2021). Decoding consumer psychology toward dietary
646 supplements: A mediation analysis between freebies and brand loyalty. *Journal of Food*
647 *Products Marketing*, 27(4), 173–187.

648 Bhuyan, D. (2016). Ever wondered why do capsules have two different colors. *RVCJ*. Retrieved
649 from <https://www.rvcj.com/ever-wondered-capsules-two-different-colors/>

650 Bloch, P. H. (1995). Seeking the ideal form: Product design and consumer response. *Journal of*
651 *Marketing*, 59(3), 16–29.

652 Caivano, J. L., & Lopez, M. A. (2007). Chromatic identity in global and local markets:
653 Analysis of colours in branding. *Journal of the International Colour Association*,
654 1(3), 1–14.

655 Chen, N., Watanabe, K., & Wada, M. (2021). People with high autistic traits show fewer
656 consensual crossmodal correspondences between visual features and tastes. *Frontiers in*
657 *Psychology*, 12:714277.

658 Chung, J., Stoel, L., Xu, Y., & Ren, J. (2012). Predicting Chinese consumers' purchase
 659 intentions for imported soy-based dietary supplements. *British Food Journal*, 114(1), 143–
 660 161.

661 Conner, M., Kirk, S. F., Cade, J. E., & Barrett, J. H. (2001). Why do women use dietary
 662 supplements? The use of the theory of planned behaviour to explore beliefs about their use.
 663 *Social Science & Medicine*, 52(4), 621–633.

664 Conner, M., Kirk, S. F. L., Cade, J. E., & Barrett, J. H. (2003). Environmental influences:
 665 Factors influencing a woman's decision to use dietary supplements. *The Journal of*
 666 *Nutrition*, 133(6), 1978S–1982S.

667 D'Cunha, N. M., Georgousopoulou, E. N., Dadigamuwege, L., Kellett, J., Panagiotakos, D. B.,
 668 Thomas, J., McKune, A. J., Mellor, D. D., & Naumovski, N. (2018). Effect of long-term
 669 nutraceutical and dietary supplement use on cognition in the elderly: A 10-year systematic
 670 review of randomised controlled trials. *The British Journal of Nutrition*, 119(3), 280–298.

671 de Sousa, M. M., Carvalho, F. M., & Pereira, R. G. (2020). Colour and shape of design elements
 672 of the packaging labels influence consumer expectations and hedonic judgments of specialty
 673 coffee. *Food Quality and Preference*, 83:103902.

674 Delivett, C. P., Klepacz, N. A., Farrow, C. V., Thomas, J. M., Raats, M. M., & Nash, R. A.
 675 (2020). Front-of-pack images can boost the perceived health benefits of dietary products.
 676 *Appetite*, 155:104831.

677 Dickinson, A., Blatman, J., El-Dash, N., & Franco, J. C. (2014). Consumer usage and reasons
 678 for using dietary supplements: Report of a series of surveys. *Journal of the American*
 679 *College of Nutrition*, 33(2), 176–182.

680 Dickinson, A., & MacKay, D. (2014). Health habits and other characteristics of dietary
 681 supplement users: A review. *Nutrition Journal*, 13:14.

682 Dickinson, A., MacKay, D., & Wong, A. (2015). Consumer attitudes about the role of
 683 multivitamins and other dietary supplements: Report of a survey. *Nutrition Journal*, 14:66.

684 Dréano-Trécant, L., Egnell, M., Hercberg, S., Galan, P., Soudon, J., Fialon, M., Touvier, M.,
 685 Kesse-Guyot, E., & Julia, C. (2020). Performance of the front-of-pack nutrition label nutri-
 686 score to discriminate the nutritional quality of foods products: A comparative study across 8
 687 European Countries. *Nutrients*, 12(5). <https://doi.org/10.3390/nu12051303>

688 Elliot, A. J., & Maier, M. A. (2012). Colour-in-context theory. *Advances in Experimental Social*
 689 *Psychology*, 45, 61–125.

690 Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical
691 power analysis program for the social, behavioral, and biomedical sciences. *Behavior*
692 *Research Methods*, 39(2), 175–191.

693 Fiszman, S., Carrillo, E., & Varela, P. (2015). Consumer perception of carriers of a satiating
694 compound. Influence of front-of-package images and weight loss-related information. *Food*
695 *Research International*, 78, 88–95.

696 Globe Newswire (2021). Outlook on the nutritional supplements global market to 2028 - by
697 product, consumer group, formulation, sales channel and region. Retrieved from
698 [https://www.globenewswire.com/news-release/2021/09/22/2301111/28124/en/Outlook-on-](https://www.globenewswire.com/news-release/2021/09/22/2301111/28124/en/Outlook-on-the-Nutritional-Supplements-Global-Market-to-2028-by-Product-Consumer-Group-Formulation-Sales-Channel-and-Region.html)
699 [the-Nutritional-Supplements-Global-Market-to-2028-by-Product-Consumer-Group-](https://www.globenewswire.com/news-release/2021/09/22/2301111/28124/en/Outlook-on-the-Nutritional-Supplements-Global-Market-to-2028-by-Product-Consumer-Group-Formulation-Sales-Channel-and-Region.html)
700 [Formulation-Sales-Channel-and-Region.html](https://www.globenewswire.com/news-release/2021/09/22/2301111/28124/en/Outlook-on-the-Nutritional-Supplements-Global-Market-to-2028-by-Product-Consumer-Group-Formulation-Sales-Channel-and-Region.html)

701 Greger, J. L. (2001). Dietary supplement use: Consumer characteristics and interests. *The*
702 *Journal of Nutrition*, 131(4 Suppl), 1339S–1343S.

703 Hanada, M. (2018). Correspondence analysis of color–emotion associations. *Color*
704 *Research & Application*, 43(2), 224–237.

705 Hess, A. C., & Melnyk, V. (2016). Pink or blue? The impact of gender cues on brand
706 perceptions. *European Journal of Marketing*, 50(9/10), 1550–1574.

707 Homburg, C., Schwemmler, M., & Kuehnl, C. (2015). New product design: Concept,
 708 measurement, and consequences. *Journal of Marketing*, 79(3), 41–56.

709 Hua, S. V., Granger, B., Bauer, K., & Roberto, C. A. (2021). A content analysis of marketing on
 710 the packages of dietary supplements for weight loss and muscle building. *Preventive*
 711 *Medicine Reports*, 23:101504.

712 Huang, L., & Lu, J. (2016). The impact of package colour and the nutrition content labels on the
 713 perception of food healthiness and purchase intention. *Journal of Food Products Marketing*,
 714 22(2), 191–218.

715 Huang, J., & Wan, X. (2019). The color–flavor incongruency effect in product evaluation and
 716 brand perception. *Journal of Consumer Behaviour*, 18(6), 484–495.

717 Jasti, S., Siega-Riz, A. M., & Bentley, M. E. (2003). Dietary supplement use in the context of
 718 health disparities: Cultural, ethnic and demographic determinants of use. *The Journal of*
 719 *Nutrition*, 133(6), 2010S–2013S.

720 Keast, R., Costanzo, A., & Hartley, I. (2021). Macronutrient sensing in the oral cavity and
 721 gastrointestinal tract: Alimentary tastes. *Nutrients*, 13:667.
 722 <https://doi.org/10.3390/nu13020667>.

723 Knapik, J. J., Steelman, R. A., Hoedebecke, S. S., Austin, K. G., Farina, E. K., & Lieberman, H.
 724 R. (2016). Prevalence of dietary supplement use by athletes: Systematic review and meta-
 725 analysis. *Sports Medicine*, 46(1), 103–123.

726 Kobayashi, E., Nishijima, C., Sato, Y., Umegaki, K., & Chiba, T. (2018). The prevalence of
 727 dietary supplement use among elementary, junior high, and high school students: A
 728 nationwide survey in Japan. *Nutrients*, 10(9). <https://doi.org/10.3390/nu10091176>

729 Kunz, S., Haasova, S., Rieß, J., & Florack, A. (2020). Beyond healthiness: The impact of traffic
 730 light labels on taste expectations and purchase intentions. *Foods*, 9(2).
 731 <https://doi.org/10.3390/foods9020134>.

732 Lester, S., Kleijn, M., Cornacchia, L., Hewson, L. Taylor, M. A., & Fisk, I. (2022). Factors
 733 affecting adherence, intake, and perceived palatability of oral nutritional supplements: A
 734 literature review. *Journal of Nutrition and Healthy Aging*. [https://doi.org/10.1007/s12603-](https://doi.org/10.1007/s12603-022-1819-3)
 735 [022-1819-3](https://doi.org/10.1007/s12603-022-1819-3).

736 Meng, Y., & Chan, E. Y. (2022). Traffic light signals and healthy food choice: Investigating
 737 gender differences. *Psychology & Marketing*, 39(2), 360–369.

738 Mick, G. D. (1986). Consumer research and semiotics: Exploring the morphology of signs,
 739 symbols, and significance. *Journal of Consumer Research*, 13, 196–213.

740 Motoki, K., Park, J., Pathak, A., & Spence, C. (2021). Constructing healthy food names: On the
 741 sound symbolism of healthy food. *Food Quality and Preference*, 90:104157.

742 Motoki, K., Saito, T., Nouchi, R., Kawashima, R., & Sugiura, M. (2019). Light colours and
 743 comfortable warmth: Crossmodal correspondences between thermal sensations and colour
 744 lightness influence consumer behavior. *Food Quality and Preference*, 72, 45–55.

745 Motoki, K., Takahashi, A., & Spence, C. (2021). Tasting atmospherics: Taste associations with
 746 colour parameters of coffee shop interiors. *Food Quality and Preference*, 94:104315.

747 Naeve, S. H. (2010). Heart pills are red, viagra is blue-when does pill color become functional-
 748 an analysis of utilitarian and aesthetic functionality and their unintended side effects in the
 749 pharmaceutical industry. *Santa Clara Computer & High Technology. LJ*, 27, 299–332.

750 Osgood, C. E. (1960). The cross-cultural generality of visual-verbal synesthetic
 751 tendencies. *Behavioral Science*, 5, 146–169.

752 Pajor, E. M., Eggers, S. M., Curfs, K. C. J., Oenema, A., & de Vries, H. (2017). Why do Dutch
 753 people use dietary supplements? Exploring the role of socio-cognitive and psychosocial
 754 determinants. *Appetite*, 114, 161–168.

755 Park, J., Motoki, K., Pathak, A., & Spence, C. (2021). A sound brand name: The role of voiced
 756 consonants in pharmaceutical branding. *Food Quality and Preference*, 90:104104.

757 Pillitteri, J. L., Shiffman, S., Rohay, J. M., Harkins, A. M., Burton, S. L., & Wadden, T. A.
 758 (2008). Use of dietary supplements for weight loss in the United States: Results of a national
 759 survey. *Obesity*, 16(4), 790–796.

760 Piqueras-Fiszman, B., & Spence, C. (2011). Crossmodal correspondences in product packaging.
 761 Assessing color–flavor correspondences for potato chips (crisps). *Appetite*, 57(3), 753–757.

762 Piqueras-Fiszman, B., & Spence, C. (2015). Sensory expectations based on product-extrinsic
 763 food cues: An interdisciplinary review of the empirical evidence and theoretical accounts.
 764 *Food Quality and Preference*, 40, 165–179.

765 Radimer, K., Bindewald, B., Hughes, J., Ervin, B., Swanson, C., & Picciano, M. F. (2004).
 766 Dietary supplement use by US adults: Data from the National Health and Nutrition
 767 Examination Survey, 1999–2000. *American Journal of Epidemiology*, 160(4), 339–349.

768 Raevskiy, A., Bubnov, I., Chen, Y. C., & Sakai, N. (2022). Differences in color representations
 769 of tastes: Cross-cultural study among Japanese, Russian and Taiwanese. In *International*
 770 *Conference on Human-Computer Interaction* (pp. 378-395). Cham: Springer.

771 Rizk, M. T., & Treat, T. A. (2015). Perceptions of food healthiness among free-living women.
 772 *Appetite*, 95, 390–398.

773 Saper, R. B., Eisenberg, D. M., & Phillips, R. S. (2004). Common dietary supplements for
 774 weight loss. *American Family Physician*, 70(9), 1731–1738.

775 Satia-Abouta, J., Kristal, A. R., Patterson, R. E., Littman, A. J., Stratton, K. L., & White, E.
 776 (2003). Dietary supplement use and medical conditions: the VITAL study. *American*
 777 *Journal of Preventive Medicine*, 24(1), 43–51.

778 Schiffman, S. S., & Dackis, C. (1975). Taste of nutrients: Amino acids, vitamins, and fatty
 779 acids. *Perception & Psychophysics*, 17(2), 140–146.

780 Schuldt, J. P. (2013). Does green mean healthy? Nutrition label colour affects perceptions of
 781 healthfulness. *Health Communication*, 28(8), 814–821.

782 Skeie, G., Braaten, T., Hjartåker, A., Lentjes, M., Amiano, P., Jakszyn, P., et al. (2009). Use of
 783 dietary supplements in the European prospective investigation into cancer and nutrition
 784 calibration study. *European Journal of Clinical Nutrition*, 63 (Suppl 4), S226–S238.

785 Spence, C. (2019). On the relationship(s) between colour and taste/flavor. *Experimental*
 786 *Psychology*, 66(2), 99–111.

- 787 Spence, C. (2021). The multisensory design of pharmaceuticals and their packaging. *Food*
 788 *Quality and Preference*, 91:104200.
- 789 Spence, C., & Di Stefano, N. (2022). Crossmodal harmony: Looking for the meaning of
 790 harmony beyond hearing. *i-Perception*, 13(1): 20416695211073817.
- 791 Spence, C., & Levitan, C. A. (2021). Explaining crossmodal correspondences between colours
 792 and tastes. *i-Perception*, 12(3):20416695211018223.
- 793 Spence, C., & Levitan, C. A. (2022). Exploring the links between colours and tastes/flavours.
 794 *Journal of Perceptual Imaging*, 4(3):000408.
- 795 Spence, C., Wan, X., Woods, A., Velasco, C., Deng, J., Youssef, J., & Deroy, O. (2015). On
 796 tasty colours and colourful tastes? Assessing, explaining, and utilizing crossmodal
 797 correspondences between colours and basic tastes. *Flavour*, 4(1):23.
- 798 Sturges, J., & Whitfield, T. A. (1995). Locating basic colours in the Munsell space. *Color*
 799 *Research & Application*, 20(6), 364–376.
- 800 Sunaga, T., Park, J., & Spence, C. (2016). Effects of lightness-location congruency on
 801 consumers' purchase decision-making. *Psychology & Marketing*, 33(11), 934–950.

802 Tao, D., Wang, T., & Wang, T. (2017). Effects of colour on expectations of drug effects: A
803 cross-gender cross-cultural study. *Colour Research and Application*, 42(1), 124–130.

804 Tao, D., Wang, T., Wang, T., & Qu, X. (2018). Influence of drug colour on perceived drug
805 effects and efficacy. *Ergonomics*, 61(2), 284–294.

806 Temussi, P. A. (2009). Sweet, bitter and umami receptors: A complex relationship.
807 *Trends in Biochemical Sciences*, 34(6), 296–302.

808 Thorndike, A. N., Gelsomin, E. D., McCurley, J. L., & Levy, D. E. (2019). Calories purchased
809 by hospital employees after implementation of a cafeteria traffic light–labeling and choice
810 architecture program. *JAMA Network Open*, 2(7):e196789.

811 Tijssen, I., Zandstra, E. H., de Graaf, C., & Jager, G. (2017). Why a “light” product package
812 should not be light blue: Effects of package colour on perceived healthiness and
813 attractiveness of sugar-and fat-reduced products. *Food Quality and Preference*, 59, 46–58.

814 van Dongen, M. V., van den Berg, M. C., Vink, N., Kok, F. J., & de Graaf, C. (2012) Taste–
815 nutrient relationships in commonly consumed foods. *British Journal of Nutrition*, 108, 140–
816 147 doi:10.1017/S0007114511005277.

817 Velasco, C., Wan, X., Knoeferle, K., Zhou, X., Salgado-Montejo, A., & Spence, C.
818 (2015). Searching for flavor labels in food products: the influence of color-flavor
819 congruence and association strength. *Frontiers in Psychology*, 6:301.

820 Velasco, C., Hyndman, S., & Spence, C. (2018). The role of typeface curvilinearity on taste
821 expectations and perception. *International Journal of Gastronomy and Food Science*, 11,
822 63–74.

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

827 Wan, X., Woods, A. T., Salgado-Montejo, A., Velasco, C., & Spence, C. (2015). Assessing the
828 expectations associated with pharmaceutical pill colour and shape. *Food Quality and*
829 *Preference*, 45, 171–182.

830 Wan, X., Woods, A. T., van den Bosch, J. J. F., McKenzie, K. J., Velasco, C., & Spence, C.
831 (2014). Cross-cultural differences in crossmodal correspondences between basic tastes and
832 visual features. *Frontiers in Psychology*, 5:1365.

- 833 Wąsowicz, G., Styśko-Kunkowska, M., & Grunert, K. G. (2015). The meaning of colours in
834 nutrition labelling in the context of expert and consumer criteria of evaluating food product
835 healthfulness. *Journal of Health Psychology*, 20(6), 907–920.
- 836 Wicker, F. W. (1968). Mapping the intersensory regions of perceptual space. *American Journal*
837 *of Psychology*, 81, 178–188.
- 838 Woods, A. T., Marmolejo-Ramos, F., Velasco, C., & Spence, C. (2016). Using single colours
839 and colour pairs to communicate basic tastes II; Foreground-background colour
840 combinations. *i-Perception*, 7:5: 10.1177/2041669516663750.
- 841 Woods, A. T., & Spence, C. (2016). Using single colours and colour pairs to communicate basic
842 tastes. *i-Perception*, 7:4: 10.1177/2041669516658817.
- 843 Wu, W.-Y., Linn, C. T., Fu, C.-S., & Sukoco, B. M. (2012). The role of endorsers, framing, and
844 rewards on the effectiveness of dietary supplement advertisements. *Journal of Health*
845 *Communication*, 17(1), 54–75.
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Supplementary materials

Appendix Table A. Frequency of colour choice for each of the nutrient categories tested in Study 1.

<i>Fat</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	3 (2.94%)	0	17 (16.67%)	8 (7.84%)	0	16 (15.69%)	12 (11.76%)	0	13 (12.75%)	12 (11.76%)	21 (20.59%)
Adj.residuals	-2.16	-3.19	2.66	-0.44	-3.19	2.32	0.94	-3.19	1.28	0.94	4.04
Adj.p	.048	.004	.172	.661	.004	.038	.382	.004	.274	.382	.001
<i>Sugar</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	1 (0.98%)	0	0	3 (2.94%)	0	9 (8.82%)	14 (13.73%)	1 (0.98%)	8 (7.84%)	60 (58.82%)	6 (5.88%)
Adj.residuals	-2.85	-3.19	-3.19	-2.16	-3.19	-0.09	1.63	-2.85	-0.44	17.47	-1.13
Adj.p	.008	.004	.004	.048	.004	.925	.142	.008	.727	<.001	.317
<i>Protein</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	1 (0.98%)	2 (1.96%)	16 (15.69%)	6 (5.88%)	2 (1.96%)	19 (18.63%)	9 (8.82%)	0	24 (25.53%)	13 (12.75%)	10 (9.80%)
Adj.residuals	-2.85	-2.5	2.32	-1.13	-2.5	3.35	-0.09	-3.19	5.07	1.28	0.25
Adj.p	.0121	.022	.032	.317	.022	.004	.925	.005	<.001	.274	.882

<i>Mineral</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	4 (3.92%)	63 (61.76%)	3 (2.94%)	11 (10.78%)	10 (9.80%)	2 (1.96%)	1 (0.98%)	0	1 (0.98%)	7 (6.86%)	0
Adj.residuals	-1.82	18.5	-2.16	0.59	0.25	-2.5	-2.85	-3.19	-2.85	-0.78	-3.19
Adj.p	.095	<.001	.048	.607	.802	.022	.010	.005	.010	.530	.005
<i>Vitamin</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	0	2 (1.96%)	1 (0.98%)	0	12 (11.76%)	18 (17.65%)	0	0	3 (2.94%)	0	66 (64.71%)
Adj.residuals	-3.19	-2.5	-2.85	-3.19	0.94	3.01	-3.19	-3.19	-2.16	-3.19	19.54
Adj.p	.003	.015	.006	.003	.348	.004	.003	.003	.034	.003	<.001
<i>Dietary fiber</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	0	0	10 (9.80%)	4 (3.92%)	68 (66.67%)	5 (4.90%)	1 (0.98%)	3 (2.94%)	0	7 (6.86%)	4 (3.92%)
Adj.residuals	-3.19	-3.19	0.25	-1.82	20.23	-1.47	-2.85	-2.16	-3.19	-0.78	-1.82
Adj.p	.004	.004	.802	.095	<.001	.172	.010	.056	.004	.477	.095

Note. Cells indicate significant nutrient-colour associations are shown in bold (adj.p < .05). Adj.residuals = Adjusted standardized residuals. Adj.p = FDR adjusted p value (Benjamini & Hochberg, 1995).

Appendix Table B. Frequency of colour choice for each of the nutrient categories tested in Study 2.

<i>Suppressing the absorption of fat</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	6 (6%)	9 (9%)	9 (9%)	8 (8%)	1 (1%)	7 (7%)	24 (24%)	1 (1%)	11 (11%)	20 (20%)	4 (4%)
Adj.residuals	-1.08	-0.03	-0.03	-0.38	-2.81	-0.73	5.19	-2.81	0.66	3.8	-1.77
Adj.p	.518	.975	.975	.861	.013	.697	<.001	.013	.697	<.001	.169
<i>Suppressing the absorption of carbohydrates</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	4(4%)	7(7%)	5(5%)	9(9%)	4(4%)	7(7%)	19(19%)	2(2%)	5(5%)	29(29%)	9(9%)
Adj.residuals	-1.77	-0.73	-1.42	-0.03	-1.77	-0.73	3.45	-2.47	-1.42	6.93	-0.03
Adj.p	.169	.571	.243	.975	.169	.571	.003	.050	.243	<.001	.975
<i>Protein</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	4 (4%)	4 (4%)	5 (5%)	12 (12%)	2 (2%)	21 (21%)	8 (8%)	2 (2%)	15 (15%)	19 (19%)	8 (8%)
Adj.residuals	-1.77	-1.77	-1.42	1.01	-2.47	4.14	-0.38	-2.47	2.06	3.45	-0.38
Adj.p	.120	.120	.213	.381	.037	<.001	.704	.037	.088	.003	.704

<i>Mineral</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	1 (1%)	39 (39%)	0	16 (16%)	7 (7%)	10 (10%)	5 (5%)	2 (2%)	1 (1%)	14 (14%)	5 (5%)
Adj.residuals	-2.81	10.4	-3.16	2.4	-0.73	0.32	-1.42	-2.47	-2.81	1.71	-1.42
Adj.p	.013	<.001	.009	.030	.514	.752	.189	.030	.013	.138	.189
<i>Vitamin</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	0	1 (1%)	0	1 (1%)	4 (4%)	39 (39%)	1 (1%)	1 (1%)	4 (4%)	2 (2%)	47 (47%)
Adj.residuals	-3.16	-2.81	-3.16	-2.81	-1.77	10.4	-2.81	-2.81	-1.77	-2.47	13.19
Adj.p	.004	.007	.004	.007	.077	<.001	.007	.007	.077	.017	<.001
<i>Dietary fiber</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	2 (2%)	1 (1%)	3 (3%)	2 (2%)	64 (64%)	3 (3%)	3 (3%)	0	3 (3%)	11 (11%)	8 (8%)
Adj.residuals	-2.47	-2.81	-2.12	-2.47	19.1	-2.12	-2.12	-3.16	-2.12	0.66	-0.38
Adj.p	.030	.018	.042	.030	<.001	.042	.042	.009	.042	.557	.704

Note. Cells indicate significant nutrient-colour associations are shown in bold (adj.p < .05). Adj.residuals = Adjusted standardized residuals. Adj.p = FDR adjusted p value (Benjamini & Hochberg, 1995).

Appendix Table C. Frequency of colour choice for each of the nutrient categories tested in Study 3.

<i>Suppressing the absorption of fat</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	8 (7.92%)	9 (8.91%)	11 (10.89%)	12 (11.88%)	7 (6.93%)	11 (10.89%)	12 (11.88%)	1 (0.99%)	6 (5.94%)	13 (12.87%)	11 (10.89%)
Adj.residuals	—	—	—	—	—	—	—	—	—	—	—
Adj.p	—	—	—	—	—	—	—	—	—	—	—
<i>Suppressing the absorption of carbohydrates</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	5 (4.95%)	9 (8.91%)	9 (8.91%)	13 (12.87%)	6 (5.94%)	9 (8.91%)	14 (13.86%)	6 (5.94%)	9 (8.91%)	17 (16.83%)	4 (3.96%)
Adj.residuals	—	—	—	—	—	—	—	—	—	—	—
Adj.p	—	—	—	—	—	—	—	—	—	—	—
<i>Protein</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	12 (11.88%)	7 (6.93%)	7 (6.93%)	10 (9.90%)	0	12 (11.88%)	4 (3.96%)	15 (14.85%)	25 (24.75%)	5 (4.95%)	4 (3.96%)
Adj.residuals	0.98	-0.76	-0.76	0.28	-3.18	0.98	-0.79	2.01	5.48	-1.45	-1.79
Adj.p	.453	.495	.459	.777	.008	.453	.160	.160	<.001	.271	.160

<i>Mineral</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	7 (6.93%)	25 (24.75%)	5 (4.95%)	18 (17.82%)	8 (7.92%)	10 (9.90%)	4 (3.96%)	5 (4.95%)	1 (0.99%)	12 (11.88%)	6 (5.94%)
Adj.residuals	-0.76	5.48	-1.45	3.05	-0.41	0.28	-1.79	-1.45	-2.83	0.98	-1.1
Adj.p	.550	<.001	.271	.013	.751	.777	.200	.271	.017	.453	.426
<i>Vitamin</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	3 (2.97%)	1 (0.99%)	0	0	7 (6.93%)	36 (35.64%)	3 (2.97%)	0	3 (2.97%)	4 (3.96%)	44 (43.56%)
Adj.residuals	-2.14	-2.83	-3.18	-3.18	-0.76	9.28	-2.14	-3.18	-2.14	-1.79	12.05
Adj.p	.040	.008	.003	.003	.450	<.001	.040	.003	.040	.080	<.001
<i>Dietary fiber</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	1 (0.99%)	3 (2.97%)	6 (5.94%)	2 (1.98%)	63 (62.38%)	7 (6.93%)	4 (3.96%)	2 (1.98%)	0	7 (6.93%)	6 (5.94%)
Adj.residuals	-2.83	-2.14	-1.1	-2.49	18.63	-0.755	-1.79	-2.49	-3.18	-0.76	-1.1
Adj.p	.017	.059	.331	.028	<.001	.450	.115	.028	.009	.450	.331

Note. Cells indicate significant nutrient-colour associations are shown in bold (adj.p < .05). Adj.residuals = Adjusted standardized residuals. Adj.p = FDR adjusted p value (Benjamini & Hochberg, 1995).

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867 **Appendix Table D.** Frequency of colour choice for each of the nutrient categories tested in Study 4.

<i>Magnesium</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	16 (16%)	6 (6%)	6 (6%)	40 (40%)	1 (1%)	3 (3%)	1 (1%)	5 (5%)	2 (2%)	20 (20%)	0
Adj.residuals	2.4	-1.08	-1.08	10.75	-2.81	-2.12	-2.81	-1.42	-2.47	3.79	-3.16
Adj.p	.025	.282	.282	<.001	.011	.047	.011	.189	.025	<.001	.006
<i>Iron</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	21 (21%)	2 (2%)	23 (23%)	32 (32%)	2 (2%)	2 (2%)	1 (1%)	4 (4%)	9 (9%)	4 (4%)	0
Adj.residuals	4.14	-2.47	4.84	7.97	-2.47	-2.47	-2.81	-1.77	-0.03	-1.77	-3.16
Adj.p	<.001	.019	<.001	<.001	.019	.019	.011	.084	.975	.084	.004
<i>Calcium</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	1(1%)	4(4%)	2(2%)	3(3%)	0	4 (4%)	1 (1%)	0	0	81 (81%)	4 (4%)
Adj.residuals	-2.81	-1.77	-2.47	-2.12	-3.16	-1.77	-2.81	-3.16	-3.16	25.01	-1.77
Adj.p	.009	.077	.021	.047	.004	.077	.009	.004	.004	<.001	.077
<i>Vitamin D</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow

Choosing frequency (%)	0	3 (3%)	3 (3%)	3 (3%)	10 (10%)	46 (46%)	9 (9%)	6 (6%)	6 (6%)	5 (5%)	9 (9%)
Adj.residuals	-3.16	-2.12	-2.12	-2.12	0.32	12.84	-0.03	-1.08	-1.08	-1.42	-0.03
Adj.p	.009	.075	.075	.075	.919	<.001	.975	.388	.388	.284	.975
<i>Vitamin C</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	0	0	0	0	1 (1%)	18 (18%)	1 (1%)	0	3 (3%)	1 (1%)	76 (76%)
Adj.residuals	-3.16	-3.16	-3.16	-3.16	-2.81	3.1	-2.81	-3.16	-2.12	-2.81	23.27
Adj.p	.003	.003	.003	.003	.005	.003	.005	.003	.034	.005	<.001
<i>Omega-3 fatty acids</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	4 (4%)	24 (24%)	8 (8%)	1 (1%)	7 (7%)	14 (14%)	12 (12%)	6 (6%)	7 (7%)	9 (9%)	8 (8%)
Adj.residuals	-1.77	5.19	-0.38	-2.81	-0.73	1.71	1.01	-1.08	-0.73	-0.03	-0.38
Adj.p	.241	<.001	.775	.027	.642	.241	.571	.571	.642	.975	.775
<i>Amino acid</i>	Black	Blue	Brown	Gray	Green	Orange	Pink	Purple	Red	White	Yellow
Choosing frequency (%)	1 (1%)	7 (7%)	7 (7%)	4 (4%)	6 (6%)	19 (19%)	14 (14%)	4 (4%)	20 (20%)	12 (12%)	6 (6%)

Adj.residuals	-2.81	-0.727	-0.727	-1.77	-1.08	3.45	1.71	1.77	3.79	1.01	-1.08
Adj.p	.018	.467	.467	.161	.381	.003	.161	.161	.001	.381	.381

868 *Note.* Cells indicate significant nutrient-colour associations are shown in bold (adj.p < .05). Adj.residuals = Adjusted standardized residuals. Adj.p =
869 FDR adjusted p value (Benjamini & Hochberg, 1995).

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