

Colourful = healthy? Exploring meal colour variety and its relation to food consumption

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A B S T R A C T

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Visual properties of food including colour are important cues when deciding what and how much to eat. Colour variety might be an intuitive cue for healthy food choices. In order to explore a colourful equals healthy association, the present study examined 486 real-life meal choices recorded by 108 participants. Participants recorded their lunch meals via mobile visual food recording, indicated the perceived meal colour variety, and added a short meal description using smartphone based ecological momentary assessment. All visual food records and description were coded by trained experts according to seven main food groups (fruit, vegetables, grains and starches, protein sources, dairy, fried foods, sugary foods). Supporting the colourful equals healthy association, increased perceived meal colour variety was related to an increased intake of vegetables and a decreased intake of sugary foods. Hence, eating colourfully seems to be a promising avenue for promoting a more intuitive but also healthy food choice strategy in consumers.

1. Introduction

Although sufficient food is available in industrialised countries, most populations risk malnutrition by failing to ingest the recommended amount of micronutrients (Cordain et al., 2005; Hesecker, 2012; Troesch et al., 2015). Scientific nutritional societies such as the U.S. Department of Agriculture (U.S. Department of Health & Human Services & U.S. Department of Agriculture, 2015) or the German Nutrition Society (Rösch & Jungvogel, 2013) therefore recommend a varied diet to provide the body with a sufficient variety of nutrients. In a similar vein but taking a different route, traditional Japanese cuisine addresses this issue by recommending cooks to include the five colours red, yellow, green, black and white in every meal to ensure nutritional value and diversity. This notion is supported by research on phytonutrients, i.e. bioactive substances including vitamins and minerals (Liu, 2013) that both increase nutritional value and give the foods their colours (e.g. alpha- and beta-carotene; Murphy, Barraj, Spungen, Herman, & Randolph, 2014; Nutrilite Health Institute, 2014). Thus, eating colourful meals might increase both nutritional value and variety of nutrients consumed, increasing the likelihood of meeting nutritional guidelines everyday.

When deciding what and how much to eat, people often need to rely on their perception of food since nutritional facts and information are seldom readily available. Visual properties of foods, including colour, are indeed important cues for food choice (Clydesdale, 1993; Renner,

Sproesser, Stok, & Schupp, 2016; Scheibehenne, Todd, & Wansink, 2010; Schulte-Mecklenbeck, Sohn, de Bellis, Martin, & Hertwig, 2013; Van der Laan, De Ridder, Viergever, & Smeets, 2011; Wansink, Painter, & North, 2005). For instance, food and beverage colours induce pre-consumption expectations about flavour identity (DuBose, Cardello, & Maller, 1980). Furthermore, colour intensity may be a cue for quality (Francis, 1995; Valentin, Parr, Peyron, Grose, & Ballester, 2016) or a more intense taste (e.g. Calvo, Salvador, and Fiszman (2001); for reviews, see also Spence (2015), Spence and Piqueras-Fiszman (2016)). Food colour also elicits expectations of nutritional value, with red foods being perceived as having a higher energy density than green foods (Foroni, Pergola, & Rumiati, 2016). Although most research on the effect of food colour on food perception has been conducted using single coloured food stimuli, food colour variety has also been shown to impact both taste perception and the amount consumed (for a summary, see Piqueras-Fiszman and Spence (2014)). For instance, multi-coloured candy was rated as more pleasant and was consumed in greater amounts compared to single coloured candy (Rolls, Rowe, & Rolls, 1982; see also Kahn and Wansink (2004) for a similar study). While these results indicate that manipulating meal colour variety might be used to increase or decrease the amount of food consumed, research is so far limited to the consumption of single types of candy.

The present study aimed to expand this line of research by exploring whether the relationship between colour variety and the amount of

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food consumed can be extended to a broader range of types of food. As both candy and fruit and vegetables are rich in colours, the question arises whether increased colour variety also leads to increased fruit and vegetable consumption. Due to low energy density and high nutritional value, the consumption of fruits and vegetables is encouraged in public health campaigns (e.g. Rösch and Jungvogel (2013), U.S. Department of Health & Human Services and U.S. Department of Agriculture (2015)). Thus, colourful meals would be considered healthier if they contained more fruits and vegetables than less colourful meals, and the suggestion to eat colourfully might be used to facilitate healthy eating.

To achieve this goal, the present study focused on lunch meals, which are the main meal of the day in Germany. Firstly, participants' food colour perception accuracy was established by comparing participants' colour perception with a colour coding by trained research staff. Secondly, colour and food group variety in lunch meals was explored to investigate whether variance in meal colours and food groups consumed was due to variability between participants or meals. Thirdly, the relationship between perceived meal colour variety and food consumption was investigated, testing a colourful equals healthy association. To maximise ecological validity and avoid the selective analysis of palatable foods such as desserts that are commonly shared on social media (Mejova, Abbar, & Haddadi, 2016; Spence, Okajima, Cheok, Petit, & Michel, 2016), data was collected in the participants' natural food consumption setting using smartphone-based ecological momentary assessment (Shiffman, 2014; Shiffman, Stone, & Hufford, 2008). The data thus represents real-life food choices with a high ecological validity (Boushey, Spoden, Zhu, Delp, & Kerr, 2016), and allowed studying intrapersonal variation.

2. Material and methods

2.1. Sample

A sample of $N = 108$ participants (81% females) was recruited using the online study pool of the University of Konstanz and short notices distributed around the university building. People were eligible for participation unless they had defective colour vision. Participants were aged 18 to 47 years ($M = 22.14$, $SD = 4.36$). Ninety-six percent of participants were students including Psychology (79%), Law (6%) or Political Science (4%) students. Participants received 0.5 h of course credit or two vouchers for coffee at the university café (total value: 2.60€) as compensation. In total, $N = 500$ meals were logged. Logging was aborted before a picture was taken for $n = 12$ meals and no picture was available for $n = 2$ meals. Therefore, the present analyses report $N = 486$ meals.

2.2. Procedure

Prior to the study period, participants were invited to the laboratory. They gave written informed consent in accordance with the Declaration of Helsinki and the guidelines of the German Society for Psychology. Participants with Android smartphones were then asked to install the smartphone application (app) movisensXS (movisens GmbH Karlsruhe; version 0.8.4203; available on Google Play for Android smartphones) and download the questionnaires. Participants without an Android smartphone ($n = 32$) received a smartphone with the app and questionnaires installed. After this session, participants were asked to record their lunch meals for four days or more over the following week. Using the app, they first filled out a questionnaire on demographic variables. Subsequently, they were asked to record their lunch meals by (1) taking a picture (see Fig. 1 for examples), (2) describing the meal and (3) rating the meal's colours, and (4) healthiness and appearance. Questionnaire data and food pictures were transferred to the server by mobile data or Wi-Fi connection. After recording at least four meals, participants returned to the laboratory to delete the questionnaires and uninstall the app or return the smartphone. Afterwards,

they were compensated for participating.

2.3. Materials

2.3.1. Perceived meal colour variety

To assess the participants' meal colour perception, two measures were applied. Firstly, participants rated the meal's colour on a 100-point visual analogue scale ranging from 'one colour' to 'very many colours'.

2.3.2. Perceived meal colours

Secondly, participants were asked to indicate whether the meal contained the following colours ((0) no/(1) yes): yellow/orange, red, green, blue, white, and other.

2.3.3. Coded meal colours

Colours were coded by trained research staff based on the meal descriptions and pictures provided by the participants. For all foods consumed in the study, a standard colour was specified in a coding manual (e.g. green for lettuce, yellow/orange for bananas, red for tomato sauce). In cases in which more than one colour was possible (e.g. bell peppers, which can be yellow/orange, red, or green), the colour was verified using the picture. In line with the questionnaire, the presence of the colours yellow/orange, red, green, blue, white, and other was coded in binary ((0) no/(1) yes).

2.3.4. Food consumption: meal composition and portion size

Similar to colour, meals were coded by trained research staff based on the food pictures and meal descriptions submitted in an open-ended text field. The foods were divided into seven food groups based on German dietary guidelines (Koelsch & Brüggemann, 2012): vegetables, fruit, grains and starches, animal and other protein sources (further referred to as 'protein'), dairy, fried foods, and desserts and other sugary foods (further referred to as 'sugary extras'). The latter two categories consisted of foods that should only be eaten in limited amounts (c.f. Onvani, Haghghatdoost, Surkan, Larijani, and Azadbakht (2016), Rösch and Jungvogel (2013)). All food items were assigned to one of the seven categories. In addition, portion sizes were estimated based on the same German dietary guidelines (Koelsch & Brüggemann, 2012). A final score for each meal was computed by dividing the portion sizes of all seven categories by the total number of portions per meal, representing the proportion of the given category in the whole meal to control for meal size.

2.3.5. Demographic variables

Participants were asked to indicate their gender, age, current occupation and field of study when they first used the app. Additionally, the participants' dietary habits (e.g. vegetarian or vegan) were assessed.

2.4. Statistical analysis

To investigate colour perception accuracy, inter-rater agreement between perceived and coded meal colours was computed in IBM SPSS 23 using Cohen's kappa (Cohen, 1960).

To account for the data's hierarchical structure, the variety in colours and food groups consumed per meal as well as the relationships between perceived meal colour variety and intake of the seven food groups were analysed with multilevel linear modelling (Hox, Moerbeek, & van de Schoot, 2010) in R 3.2.3 using the packages lme4 version 1.1–11 (Bates et al., 2016) and lmerTest 2.0–30 (Kuznetsova, Brockhoff, & Christensen, 2016). The individual meals define Level 1 (the lower level) of the hierarchy and were nested within participants who define Level 2 (the higher level). Variety of meal colour and food groups consumed was analysed using an intercept only model, which separates the total variance into variance between meals and variance between participants. Using this model, intraclass correlations (ICC)



Fig. 1. Examples of meal pictures taken by participants.

were computed, which estimate the proportion of variance explained by the participants compared to the total variance.

The intake of seven food groups was modelled as a function of perceived meal colour variety within participants to test whether the proportion of the respective food category changed as a function of perceived meal colour variety. Perceived meal colour variety as a Level 1 predictor was group-mean centred, as recommended by [Enders and Tofghi \(2007\)](#). For each food category, two models were computed. First, a random slopes model allowing both intercept and slope to vary was computed in order to model whether participants differ both in mean consumption and the relationship between perceived meal colour variety and consumption. Secondly, a random intercept model allowing only the intercept to vary was computed to model whether participants differed only in mean consumption and not in the relationship between perceived meal colour variety and consumption. Standardised regression coefficients were computed following the procedure suggested by [Hox et al. \(2010\)](#). If significant, both models were then compared using a deviance test ([Hox et al., 2010](#)). A non-significant deviance test indicates that the less complex model (i.e. random intercept model) is preferred, while a significant deviance test indicates that the more complex model (i.e. random slopes model) is preferred. In the latter case, the percentage of positive and negative slopes was computed following the procedure suggested by [Hox et al. \(2010\)](#).

3. Results

3.1. Accuracy of colour perception

To test the accuracy of colour perception, Cohen's kappa ([Cohen, 1960](#)) was computed for all six colours. While agreement for the colours red and green was substantial ($\kappa_{\text{red}} = 0.69$, $\kappa_{\text{green}} = 0.77$), agreement for the other colours was fair to moderate ($\kappa_{\text{yellow/orange}} = 0.45$, $\kappa_{\text{blue}} = 0.10$, $\kappa_{\text{white}} = 0.33$, $\kappa_{\text{other}} = 0.34$).

3.2. Colour and food group variety in lunch meals

3.2.1. Colour variety

Average perceived colour variety was moderate, but data showed a substantial variation between meals ($M = 52.26$, $SD = 24.36$, range 0–100, $ICC = 0.13$). The ICC indicated that 13% of variance was due to differences between participants and 87% of variance was due to differences between meals. Of all recorded meals, 83.7% contained the colours yellow or orange, 66.2% contained red, 61.2% contained green, 12.4% contained blue, 61.6% contained white and 61.0% contained other colours.

3.2.2. Food group variety

The most frequently consumed food groups were vegetables (in 79.0% of meals; $ICC = 0.23$) and grains and starches (78.8%; $ICC = 0.07$). Dairy was present in 42.1% of meals ($ICC = 0.05$), while 18.4% of meals included fruit ($ICC = 0.29$) and 16.7% included fried foods ($ICC = 0.02$). Another 35.1% of meals contained protein ($ICC = 0.11$) and 11.0% of meals contained sugary extras ($ICC = 0.10$). Again, substantial variation between meals was found for all food groups as indicated by the ICC: while 2–29% of variance was due to differences between participants, 71–98% of variance was due to differences between meals.

3.3. Relationships between perceived meal colour variety¹ and food consumption

Multilevel models were computed separately for all seven food

¹ Similar results emerged when coded meal colours were used as a predictor. The more colours the meal contained, the more vegetables ($b = 0.022$, $t(135.85) = 2.01$, $p = .046$) and less sugary extras ($b = -0.020$, $t(132.44) = -2.50$, $p = .014$) were consumed. For both food groups, the random slopes models were preferred ($\chi^2_s(df = 2) \geq 11.55$, $ps \leq 0.003$), indicating differences in the magnitude and direction of the effect between participants. For vegetable consumption, 69% of slopes were positive, while 31% of slopes were negative. For the consumption of sugary extras, 70% of slopes were negative,

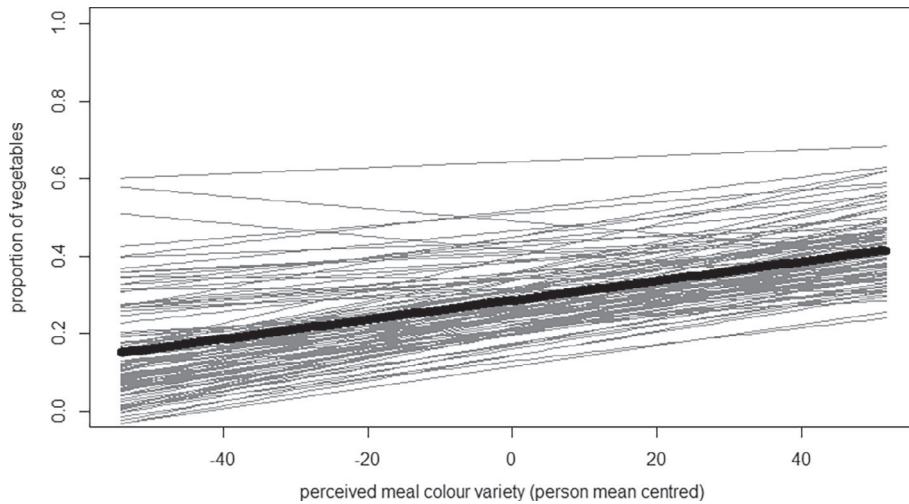


Fig. 2. Association between perceived meal colour variety and proportion of vegetables consumed in the meal. Each thin grey line represents a regression line for one participant. The thick black line represents the overall regression line.

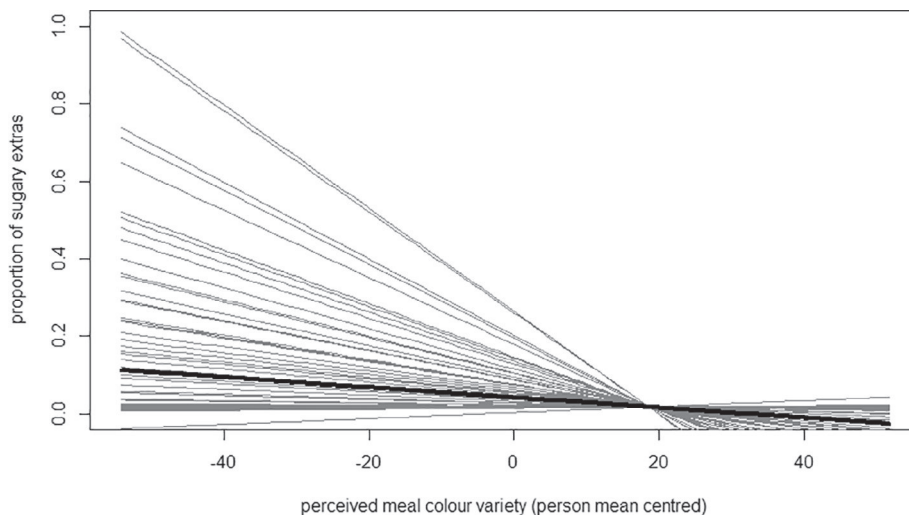


Fig. 3. Association between perceived meal colour variety and proportion of sugary extras consumed in the meal. Each thin grey line represents a regression line for one participant. The thick black line represents the overall regression line.

groups. A significant positive relationship with perceived meal colour variety emerged for vegetables, indicating a higher proportion of vegetables in meals perceived as more colourful. When comparing the random slopes ($\beta = 0.27$, $t(65.58) = 4.99$, $p < .001$) and random intercept models ($\beta = 0.28$, $t(373.00) = 5.89$, $p < .001$), the random intercept model assuming no differences in the individual slopes was preferred ($\chi^2(df = 2) = 4.20$, $p = .122$). Thus, the found relationship between meal colour variety and proportion of vegetables consumed was comparable between participants (see Fig. 2).

Furthermore, a significant negative relationship emerged between perceived meal colour variety and the proportion of sugary extras. When comparing the random slopes ($\beta = -0.22$, $t(87.62) = -3.06$, $p = .003$) and random intercept models ($\beta = -0.25$, $t(371.10) = -4.97$, $p < .001$), the random slopes model was preferred ($\chi^2(df = 2) = 71.20$, $p < .001$), indicating that the relationship between perceived meal colour variety and the proportion of sugary snacks consumed differed between participants. Sixty-six percent of slopes were negative, indicating that a greater perceived meal colour variety was associated with a lower proportion of sugary extras, while 34% of slopes were positive, indicating that a greater perceived meal

colour variety was associated with a higher proportion of sugary extras (see Fig. 3).

For all other food groups, no significant relationships with perceived meal colour variety were found (see Table 1 for a summary of all models).

4. Discussion

In the present research, the perceived colour variety of lunch meals and its relationship to the consumption of seven food groups was investigated. Perceived meal colour variety and the consumption of different food groups varied substantially between meals, indicating a great variability of eating behaviour within participants. Furthermore, results revealed that increased perceived meal colour variety was associated with an increased proportion of vegetables consumed and a decreased proportion of sugary extras consumed. As a greater proportion of vegetables and a smaller proportion of sugary extras increases the overall nutritional value of the meal, these results provide support for the proposed colourful equals healthy association.

As most people consume too little fruit and vegetables (Hall, Moore, Harper, & Lynch, 2009) and too much sugar, the need for public health initiatives to facilitate healthier diets is high (World Health Organization., 2007). Many diet programs have been shown to be devoid of beneficial long-term effects (Mann et al., 2007), possibly due to shortcomings like a focus on restrictions or complex set of rules (Freedman, King, & Kennedy, 2001; Hession, Rolland, Kulkarni,

(footnote continued)

while 30% of slopes were positive. Furthermore, the more colours the meal contained, the more protein ($b = 0.020$, $t(318.20) = 2.79$, $p = .006$) was consumed. As the random intercept model was preferred ($\chi^2(df = 2) = 0.56$, $p = .754$), no differences between participants were assumed for this relationship.

Table 1

Results of the multilevel models to analyse the relationship between perceived meal colour variety and consumption of seven food categories.

Predictor	Random slopes model (fixed effects)					Random intercept model (fixed effects)				
	<i>b</i>	<i>SE</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>b</i>	<i>SE</i>	<i>t</i>	<i>df</i>	<i>p</i>
<i>Model 1: Proportion of vegetables</i>										
Intercept	0.286	0.014	20.63	104.30	< 0.001	0.286	0.014	20.67	104.00	< 0.001
Perceived meal colour variety	0.003	0.001	4.99	65.58	< 0.001	0.003	0.000	5.89	373.00	< 0.001
<i>Model 2: Proportion of sugary extras</i>										
Intercept	0.042	0.008	5.34	106.73	< 0.001	0.042	0.008	5.38	101.30	< 0.001
Perceived meal colour variety	-0.001	0.000	-3.06	87.62	0.003	-0.002	0.000	-4.97	371.10	< 0.001
<i>Model 3: Proportion of fruit</i>										
Intercept	0.064	0.011	6.04	97.53	< 0.001	0.063	0.010	6.07	96.40	< 0.001
Perceived meal colour variety	-0.000	0.000	-0.36	43.90	0.721	-0.000	0.000	-1.04	364.90	0.301
<i>Model 4: Proportion of protein</i>										
Intercept	0.094	0.008	11.95	102.41	< 0.001	0.094	0.008	11.97	102.30	< 0.001
Perceived meal colour variety	0.000	0.000	1.11	67.93	0.269	0.000	0.000	1.35	373.20	0.179
<i>Model 5: Proportion of grains and starches</i>										
Intercept	0.272	0.009	30.28	104.61	< 0.001	0.272	0.009	30.30	104.30	< 0.001
Perceived meal colour variety	-0.001	0.000	-1.20	81.40	0.235	-0.000	0.000	-0.73	376.80	0.464
<i>Model 6: Proportion of dairy</i>										
Intercept	0.129	0.009	14.66	115.86	< 0.001	0.129	0.009	14.79	101.00	< 0.001
Perceived meal colour variety	-0.000	0.000	-0.92	84.37	0.363	-0.000	0.000	-0.55	373.90	0.583
<i>Model 7: Proportion of fried foods</i>										
Intercept	0.058	0.007	7.92	135.05	< 0.001	0.058	0.007	7.94	106.30	< 0.001
Perceived meal colour variety	-0.000	0.000	-0.33	102.78	0.746	-0.000	0.000	-0.87	380.00	0.386

Wise, & Broom, 2009) that makes them hard and frustrating to adhere to (Julia et al., 2014). According to the present research, 'eat[ing] your colours' (Pollan, 2009, p. 57) might be a simpler way to facilitate healthy eating. Focusing on visual cues is a natural approach to making food choices (Renner et al., 2016; Schulte-Mecklenbeck et al., 2013). Moreover, the present research showed that food colours can be accurately identified by participants and that eating colourfully might therefore be an implicitly understood instruction. Interestingly, increased perceived meal colour variety was associated with an increased proportion of vegetables consumed across participants. This suggests that eating colourfully might be a way to improving the healthiness of meals by increasing the proportion of vegetables without the need to take individual moderators such as gender or food preferences into account.

Interestingly, while one could have expected a similar relationship to emerge for fruit, no significant association was found between perceived meal colour variety and the proportion of fruit consumed. This might be explained by the fact that fruits like apples or bananas, which are the most commonly consumed fruits in Germany (Bundesministerium für Ernährung und Landwirtschaft, 2013), are usually consumed as one piece, while vegetables are often consumed as mixed vegetables on the side or in stews.

Contrary to the universally positive relationship between perceived meal colour variety and vegetable consumption, differences between participants emerged regarding the magnitude and direction of the relationship between perceived meal colour variety and the proportion of sugary extras consumed. For two thirds of the sample, a negative relationship was found, meaning that more colourful meals contained a smaller proportion of sugary extras, while the opposite effect was observed for the remaining participants. This difference between participants indicates that the relationship might be influenced by moderators that were not assessed in the present study. For example, participants might differ in the types of sweet foods that they prefer. Some sweets like the candy used in previous research (Kahn & Wansink, 2004; Rolls et al., 1982) are multi-coloured and therefore induce a high perceived meal colour variety, but many other sweet foods like rice pudding, chocolate or confectionery are less colourful, and thus might be associated with a lower perceived meal colour variety. In the literature,

other moderators of the relationship between colour and food perception have been discussed, such as culture (Shankar, Levitan, & Spence, 2010; Velasco et al., 2016; Woods, Marmolejo-Ramos, Velasco, & Spence, 2016) and age (Philipson, Clydesdale, Griffin, & Stern, 1995). As the present sample consisted of white, western students in a comparably narrow age range, systematically testing these moderators for the colourful equals healthy association is open to future research. Furthermore, as the present study investigated meal colour variety in lunch meals where only a small proportion contained sugary extras, limited conclusions can be drawn about associations between meal colour variety and snack consumption or other meals such as breakfast and dinner. Other colourful foods such as breakfast cereals, which are calorie dense and high in sugar, might contradict the general colourful equals healthy association. Therefore, future studies should test to what extent the present findings can be transferred to other types of meals to investigate the generalizability of the colourful equals healthy association to other study populations and types of meals.

In the literature, it is suggested that colourful meals might lead to eating more due to increased pleasure or decreased sensory-specific satiety (Piqueras-Fizman & Spence, 2014), which might also lead to an increased calorie intake. While the presented results suggest that eating colourfully induces a greater consumption of vegetables, participants also consumed fewer sugary extras, which have a higher energy density than vegetables. Thus, consuming more colourful meals may not increase caloric intake. However, this interpretation is speculative since the present data preclude definite conclusions about calorie consumption.

To keep the burden on participants low, the present study assessed food consumption by asking the participants to take a picture of their food before they ate. However, no picture was taken at the end of the meal, precluding accurate records of exactly how much food was consumed. Although research suggests people usually eat everything they serve themselves (Wansink & Johnson, 2015), future studies should account for leftovers when estimating the amount of food consumed.

Another limitation of the study was the comparably low accuracy of participants when identifying blue foods. As many foods categorised as blue in the coding manual look and were perceived by participants as

being purple (e.g. aubergines, plums), the questionnaire needs to be adapted in future studies to better reflect the nuances of foods' colours.

5. Conclusions

The present study investigated the relationship between perceived meal colour variety and the consumption of seven food groups in participants' real-life lunch consumption setting. Increased perceived meal colour variety was associated with a healthier eating pattern, indicated by an increased proportion of vegetables and a decreased proportion of sugary extras consumed, supporting a colourful equals healthy association. This research has laid the foundation for future behaviour change interventions by showing that eating colourful meals might be a promising avenue for promoting a more intuitive but also healthy food choice strategy in consumers. Hence, making the fabled colourful equals healthy association explicit might contribute to 'boosting' healthy food choices (c.f. Gigerenzer and Gaissmaier (2011), Grüne-Yanoff and Hertwig (2016)).

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