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Research report

The effect of the color red on consuming food does not depend on achromatic (Michelson) contrast and extends to rubbing cream on the skin

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ABSTRACT

Recent literature suggests that individuals may consume less food when this is served on red plates. We explored this intriguing effect in three experiments. Independent groups of participants were presented with constant amounts of popcorns, chocolate chips, or moisturizing cream, on red, blue, or white plates. They were asked to sample the foods (by tasting them) or the cream (by rubbing it on the hand and forearm) as they wished and to complete mock "sensory analysis" questionnaires. Results confirmed that red plates reduce taste-related consumption and extended this effect to the touch-related consumption of moisturizing cream. Suggesting that the effect was not due to a decrease in the consciously experienced appeal of products on red plates, overall appreciation of the foods or cream did not differ according to plate color. After careful photometric measures of the materials used for each food-plate pairing, we determined that food and cream consumption was not predicted by Michelson (achromatic) contrast. Although the origin of the intriguing effect of the color red on consumption remains unclear, our results may prove useful to future potential explanations.

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Introduction

According to a recent report, serving food on red plates can reduce food consumption (Genschow, Reutner, & Wänke, 2012). This report is interesting both practically and scientifically. On the practical side, it brings empirical evidence to bear on a issue that is muddled by contradictory common-sense opinions. The possibility of using color to control food consumption is attractive for weight-loss programs and possibly even for the treatments of eating disorders. However, guidelines on the possible use of color to reduce calorie intake often lack a solid empirical basis. On the scientific side, the report adds to a large literature on the effects of color on cognition and behavior (Bellizzi & Hite, 1992; Clydesdale, 1993; Elliot & Maier, 2007; Mehta & Zhu, 2009; Spence, Levitan, Shankar, & Zampini, 2010; Stroebele & De Castro, 2004). This literature suggest that processes as diverse as taking decisions, solving problems, tasting, and eating may be influenced by contextual color cues. It is presently not clear, however, whether such color effects share a common basis and what this basis (or bases) might be. To illustrate the importance of further pursuing these issues, we start with an overview of the current evidence concerning color effects on food consumption.

Genschow et al. (2012) reported two studies of the effect of plate color on consumption. In the first study, they asked 41 males to evaluate drinks served in plastic cups. In one condition, the cups had red labels whereas in the other they had blue labels. Participants drank significantly less from the red-labeled cups than from the blue ones. In the second study, they invited 130 participants to snack on pretzels while filling an unrelated questionnaire. Depending on the experimental condition, the pretzels were presented on white, blue, or red paper plates. Participants in the red condition ate significantly less pretzels than those in the blue or white conditions. These findings are intriguing. For several reasons, however, they are not conclusive. For one, the design of the first study did not include a baseline condition. Therefore it is impossible to determine if participants actually drank less from the red-labeled cups, or more from the blue-labeled ones. Bluish colors are typical of bottled water labels, and it cannot be excluded that this may have produced a small bias (see Ngo, Piqueras-Fiszman, & Spence, 2012). The design of the second study did include a white plate baseline. Even for this study, however, an alternative explanation is that the results depended on contrast. There is evidence that enhancing visual contrast may make consumers more aware of how much they are eating (van Ittersum & Wansink, 2012), make food more appetizing (Piqueras-Fiszman, Alcaide, Roura, & Spence, 2012), and even boost food and liquid intake in Alzheimer's patients (Dunne, Neargarder, Cipolloni, & Cronin-Golomb, 2004).

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Given the colorimetric information provided by Genschow et al. (2012), it is difficult to rule out the contrast account described above. Their paper did not provide photometric measures of the stimuli but HLS (hue–lightness–saturation) values, and only for the red and blue plates. The HLS color space was introduced (Joblove & Greenberg, 1978), and is used widely, for computer graphics applications. It is not an absolute colorimetric space but a method for ordering colors on a computer display. As such it requires specifying the characteristics of the used RGB space, including the gamma correction, to specify a color precisely. With regard to an actual object in a natural setting, there is no principled way of converting HLS lightness to psychophysical luminances, even if all were provided. For these reasons it is not possible to determine how strongly the pretzels contrasted with the different plates.

In a related study, van Ittersum and Wansink (2012, study 5) directed 60 lunch goers to buffet tables offering pasta premixed either with a red tomato sauce or with a cream-based (“Alfredo”) white sauce. At these tables, participants were randomly given either a white or a red plate. The results indicated that participants receiving a white plate served themselves less when offered red-sauce pasta, and more when offered white-sauce pasta. Conversely, participants receiving a red plate served themselves less when offered the white-sauce pasta, and more when offered the red-sauce pasta. This finding seems consistent with the hypothesis that contrast, rather than the specific color of the plate, is the causal factor in reducing food consumption. However, van Ittersum and Wansink also did not provide colorimetric measures or information about materials and illumination conditions for their study. In addition, their study assessed serving, not eating. Thus there is no way of knowing if participants ate more or less as as a function of plate colors or color contrast. For these two reasons, the conclusions of this study about color effects on food consumption also remain tentative.

In the present work we further explored the putative effect of plate color red on consumption. Specifically, we were interested in doing three things. First, we wanted to test if the effect of red plate on food consumption is robust and can be replicated in a different setting. Such a replication is interesting in itself given recent debates about replicability in the psychological sciences (see e.g. Pashler & Wagenmakers, 2012). Second, we aimed at determining the role of achromatic contrast as the potential causal factor in reducing consumption. As discussed above, this issue remained unresolved in previous studies. We believe that addressing this issue properly requires making a critical conceptual distinction between achromatic (relative change in intensity) and chromatic (difference in color *per se*) contrast. Third, and final, we were interested in determining whether effects are specific to the consumption of food or generalize to other sensory domains. Specifically, we tested the touch-related consumption of moisturizing cream presented on red, blue, or white plates. If such generalization can be demonstrated, this would have interesting consequences for the our understanding of the multisensory processes affecting consumption, as well as potential practical implications for color choices in packaging, branding, and retail store design.

Methods

Participants

A total of 240 healthy volunteers participated in the three studies. Of these, 90 (45 females) participated in the popcorn study, 75 (45 females) in the chocolate chip study, and 75 (39 females) in the moisturizing cream study. They were recruited within the community of students at the University of Parma and among participants at local continuing education courses for professionals taught by the second author. The median ages of participants in the popcorn, chocolate, and cream studies were 23 (range 18–50), 25 (19–58), and 33 years (19–66), respectively.

Design

To rule out the possibility that some participants made guesses as to the purpose of the study, plate color in all studies was treated as a between-participant factor. Thus in all studies we had separate groups of participants for the red, blue, or white plates. We also recorded and analyzed potential moderators of consumption during the study: the reported time elapsed since the last meal (for the popcorn and chocolate studies) and the reported type of skin (for the moisturizing cream study). Finally, in all studies we considered the potential moderating effect of overall appreciation towards the product, as recorded by a specific item in the mock questionnaires.

Stimuli and equipment

We used two sets of commercially available red, blue, and white plastic plates. The first set (diameter = 22 cm) was used in the popcorn study. The second set (diameter = 21 cm) was used in the chocolate and in the cream studies. Although the two sets were from different brands and were slighlty different in size, they were essentially identical in color appearance. The popcorns, chocolate chips, and moisturizing cream were also from commercially available, standard brands. Photometric measurements of the plates and foods or cream were performed using a Corob spectrophotometer (integrating sphere, di/8 deg) and with a Minolta LS100 Luminance meter. In addition, in the chips and in the cream studies we used a Laica BX9310 digital scale (maximum load 120 g, random error 0.05 g) to set a constant amount of chocolate or cream on the plates. No scale was necessary in the popcorn study as the amount was determined simply by counting the corns.

Questionnaires

In all three studies, mock questionnaires were developed to encourage participants to sample the foods or the cream without mentioning our specific interest on the effect of plate color. In the popcorn study, the questionnaire consisted of 20 statements. In the chip and cream studies, the questionnaires consisted of 40 statements. The number of statements in the second and third experiments was increased because we noted that participants completed the questionnaire of experiment 1 relatively quickly. We reasoned that a longer list could encourage them to sample the products more often. The full lists of statements (http://www2.unipr.it/~brunic22/questApp.pdf) are available online. Participants responded by reporting degree of agreement on a 1–5 scale, where 1 corresponded to complete disagreement, 5 to complete agreement, and 3 to indifference. Statements were adapted from standard sensory analysis questions. In the popcorn and chip studies, they referred to taste- or flavor-related sensory qualities (e.g. “This product is salty”, for popcorn, or “This product reminds me of nuts”, for chocolate chips). In the cream study, to touch- or smell-related qualities (e.g. “This cream is sticky”, “The perfume reminds me of grass”). We were not especially interested in these items and did not make an effort to validate them psychometrically. In all questionnaires, however, we included an item probing overall liking and appreciation of the food or cream (“Overall I liked this product”). This item was added specifically to control for the moderating effect of product appreciation on consumption and to test possible interactions with plate color.

Procedure

The research was conducted in accordance with the ethical standards of the Italian Board or Psychologists (see http://www.psy.it/codice_deontologico.html) and of the Italian Psychological Society (AIP, see http://www.aipass.org/node/26). Given that the experiment did not involve clinical tests, use of pharmaceuticals or medical equipment, did not involve the use of deception or involve participant discomfort in any other way, approval of the Ethics Committee for Clinical Research of the University of Parma was deemed unnecessary. In all three studies, participants were assigned randomly to one of three plate color conditions. All participants were tested individually or in groups of no more than four individuals. When more than one was tested simultaneously, all plate colors were the same. All test were performed in quiet rooms equipped with light gray tables. Upon entering the room, participants found the plates already readied with the appropriate stimulus materials in them. Foods and cream were kept at room temperature. Next to the plates, they found the questionnaire and a pen. They were instructed to sample the popcorns or the chocolate chips and to evaluate them for sensory qualities using the provided questionnaires. The foods were sampled by tasting them, whereas the cream was sampled by rubbing it on the hands and forearms. Participants were told that they could sample as much as they felt was necessary to complete the questionnaire, that there were no correct or incorrect answers, and that there was no time limit. Upon completion of the questionnaires, participants that so desired were informed as to the purposes of the study. Before the participants entered the room, experimenters prepared the plates with fixed amounts of 20 popcorns (by counting), 50 g of chocolate chips or 50 g of moisturizing cream (using the digital scale). Popcorns and chips were randomly spread out over the entire plate, whereas the cream was placed on the plate center forming an approximately circular mass with a diameter of about 1/3 the plate diameter. Upon completion of the questionnaires, experimenters measured again the amounts in the plates and computed the difference with initial amount to determine consumption, which was then entered in an Excel spreadsheet recording the participants' age, sex, weight, and time since the last meal (popcorn and chocolate chip experiments) or skin type (cream experiment). Finally, all responses to the mock questionnaire were also recorded. All data used in the study were recorded anonymously.

Photometric measurements

The colorimetric characteristic of all stimulus materials used in the studies are presented in Table 1. Spectral measurements were performed with a white sheet placed underneath the plates and using CIE illuminant A. Given that in the study settings the plates were placed on white tabletops and viewed under artificial illumination, these conditions closely mimicked those of the actual experiments. Luminance measurements were performed under a TL84 fluorescent lamp 2 m above the measured object.

Because luminance readings varied slightly depending on location on the measured object, several measures were taken and then averaged.

To quantify colorimetric properties we used the CIE 1976 $L^*a^*b^*$ color space (also known as CIELAB). The Lab color space is widely employed in industry and computer displays as approximately uniform in terms of perceptual units (i.e. similar changes in the coordinates correspond to similar perceived changes). The L^* dimension of the space is roughly proportional to log-luminance, and captures perceived changes along the black–white achromatic color continuum. The a^* and b^* dimensions define a chromatic plane with axes corresponding to the red–green and blue–yellow opponent continua. Thus, the degree of similarity between two colors can be measured by their Euclidean distance on the a^*b^* plane (see CIE, 2004; Fairchild, 2005). To quantify achromatic contrast, for each pairing of plate and food or cream we computed the Michelson ratio, $(L\text{max} - L\text{min})/(L\text{max} + L\text{min})$, where L is luminance, the luminous intensity of light impinging on the eye weighted by the eye's average spectral sensitivity (see Michelson, 1927; Wyszecki & Stiles, 2000). The Michelson ratio is commonly employed in psychophysics to represent the local change in achromatic intensity between two objects.

Table 1
Colorimetric coordinates (CIELAB space) and luminance (cd/m^2) of the red, blue, and white plates and of the foods and moisturizing cream used in the three studies.

	L	*a*	*b*	cd/m^2
Popcorn study				
Red	53.9	52.1	39.6	19.4
Blue	31.9	−2.0	−40.6	5.6
White	91.0	−0.4	−1.0	79.34
Corns	93.8	1.1	14.4	67.7
Chocolate study				
Red	53.9	51.4	42.2	17.6
Blue	30.2	−3.7	−33.5	7.7
White	91.0	−0.8	−5.9	73.5
Chips	44.5	1.7	0.0	6.27
Cream study				
Red	53.9	51.4	42.2	17.6
Blue	30.2	−3.7	−33.5	7.7
White	91.0	−0.8	−5.9	73.5
Cream	88.6	−0.3	−0.2	83.5

Results

Popcorn study

Popcorn consumption decreased in the red relative to the blue and white plate groups (Fig. 1, top left). The average number of popcorns (±sem) consumed by our participants was 6.3 ± 0.4 (minimum = 1; maximum = 16). The averages of the blue and white groups were 6.7 ± 0.7 and 7.3 ± 0.7, whereas the average of the red group was substantially smaller, 4.8 ± 0.7.

We also observed an increase in average consumption in participants that reported higher overall appreciation in the relevant questionnaire item. Group averages were 5 ± 0.41, 5.3 ± 0.5, 7.6 ± 0.4.6, and 6.5 ± 1.7 for participants with levels of agreement of 2, 3, 4, and 5, respectively (no participant reported a level of 1). However, appreciation did not vary with plate color. Mean agreement scores were 3.4 ± 0.17, 3.5 ± 0.18, and 3.5 ± 0.16 for the blue, red, and white groups, respectively.

We tested the effect of plate color by means of a between-factor analysis of variance (ANOVA), using plate color and appreciation level as predictors. Because the distribution of the number of consumed popcorns was skewed with a marked right tail, the variable was subjected to a logarithmic transformation before performing this and subsequent analyses. This ANOVA revealed significant effects of appreciation, $F(3,78) = 3.5$, $p < 0.05$ as well as of plate color, $F(2,78) = 9.8$, $p < 0.001$. The two-way interaction failed to reach significance, $F(6,78) = 1.4$, N.S. Scheffé post hoc pairwise comparisons revealed differences between red and blue and red and white, $p < 0.01$ and 0.001, but not between blue and white. To check that our outcomes were not critically affected by log transformations, here and elsewhere we also run separate analyses using the untrasformed values. All outcomes remained essentially identical, except for reductions in the size of the computed F-values and marginal changes in the probabiities associated with the Scheffè post hoc tests.

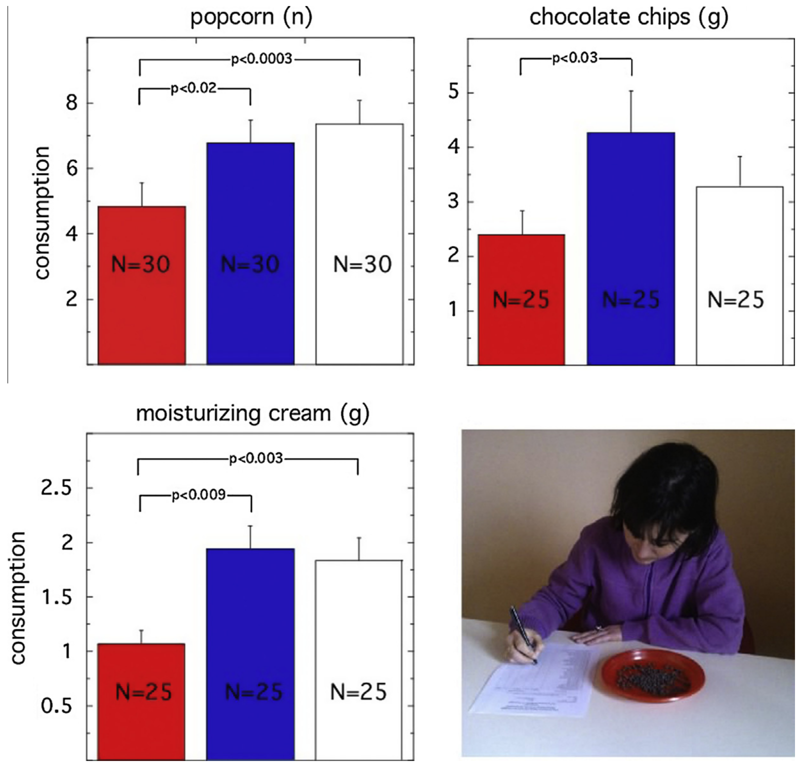

Fig. 1. Red plates reduce the consumption of foods (top) and of moisturizing cream (bottom left). Participants sampled the foods or cream to fill out mock "sensory analysis" questionnaires (bottom right). Bar colors correspond to plate colors; bar heights represent average consumption; error bars are one standard error of the mean. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The median elapsed time since the participants' last meal was 120 min. The values corresponding to the minimum, maximum, 1st, and 3rd percentiles of the distribution were 5, 600, 60, and 200 min, respectively. To rule out that color effects were due to differences in these times, we performed an additional analysis of covariance (ANCOVA) using times since the last meal as the numerical covariate and plate color as the predictor, and removing the variability due to time before testing for the effect of color. The outcome of this second analysis again supported a significant effect of plate color, $F(2,86) = 5.7$, $p < 0.005$, but provided no evidence for an effect of time, $F(1,86) < 1$.

Chocolate chip study

We observed a decrease in the consumption of the chips in the red relative to the blue and white groups (Fig. 1, top right). The average weight of the consumed chips (±sem) was 3.3 ± 0.3 g (minimum = 0.05 g; maximum = 11.7 g). The averages of the blue and white groups were 4.3 ± 0.5 g and 3.3 ± 0.5 g, whereas the average of the red group was 2.3 ± 0.4 g. Average consumption as a function of the participants' overall appreciation of the chips (questionnaire item n. 39) was 3.9 ± 1.6, 3.1 ± 0.7, 3.1 ± 0.4.6, and 3.6 ± 0.5 for participants with agreement levels of 2, 3, 4, and 5, respectively (again no participant reported a level of 1). As in the previous study, we did not observe effects of plate color on the questionnaire results. In particular, there was no sign of effects of appreciation, as reflected by the agreement to item 39. Median scores for this item were 4 in all color groups, and averages were 4.1 ± 0.1, 4.2 ± 0.2, and 4.1 ± 0.2 for the blue, red, and white groups, respectively.

As in the popcorn study, we tested the effect of plate color by means of a between-factor analysis of variance (ANOVA), using only plate color and appreciation level as predictors. This ANOVA confirmed a significant effect of plate color, $F(2,64) = 4.9$, $p < 0.01$. Scheffé post hoc pairwise comparisons revealed differences between red and blue and, $p < 0.05$, but not between red and white and blue and white. Conversely, there were no significant effects of appreciation, $F(3,64) = 2.3$, N.S., or of the two-way interaction, $F(5,64) = 1.7$, N.S.

The median elapsed time since the participants' last meal was 165 min. The values corresponding to the minimum, maximum, 1st, and 3rd percentiles of the distribution were 30, 820, 93, and 210 min, respectively. To rule out that color effects were due to differences in these times, as in the popcorn study we performed an additional ANCOVA using times since the last meal as the numerical covariate and plate color as the predictor. This again supported a significant effect of plate color, $F(2,71) = 3.3$, $p < 0.05$, but provided no evidence for an effect of time, $F(1,71) = 2.25$, N.S.

Moisturizing cream study

We observed a decrease in the use of cream in the red relative to the blue and white groups (Fig. 1, bottom left). The average consumed cream was 1.6 ± 0.1 g (minimum = 0.2 g; maximum = 5.4 g). The averages of the blue and white groups were 1.9 ± 0.2 g and 1.8 ± 0.2 g, whereas the average of the red group was 1.0 ± 0.1 g. Consumption was related to overall satisfaction with the cream (questionnaire item n. 38). Averages were 1.1 ± 0.6, 1.6 ± 0.3, 1.6 ± 0.0.1, and 1.8 ± 0.3 for participants with levels of agreement equal to 2, 3, 4, and 5, respectively (again no participant choose 1). Once more, however, we did not observe effects of plate color on questionnaire results. In particular, there was no sign of effects of appreciation, as reflected by the agreement to item 38. Median scores for this item were 4 in all color groups, and averages were 3.9 ± 0.16, 3.7 ± 0.18, and 3.9 ± 0.15 for the blue, red, and white groups, respectively.

Given this pattern of results, we tested the effect of plate color by means of a between-factor analysis of variance (ANOVA), using satisfaction level and plate color as predictors. This ANOVA revealed a significant effect of plate color, $F(2,69) = 6.1$, $p < 0.004$, but not of satisfaction, $F(3,69) < 1$. The two-way interaction also did not reach significance, $F(5,64) = 2.3$, N.S. Scheffé post hoc pairwise comparisons revealed differences between red and blue and red and white, $p < 0.01$ and 0.01, but not between blue and white.

Participants differed in their self-reported skin type. Specifically, 27 of them reported having oily skin or composition skin (oily only in some areas), 31 reported having normal skin, and 17 reported having dry skin. As one would expect, we observed average differences in cream consumption in groups reporting different skin types. Participants reporting oily or composition skin consumed an average of 1.3 g of cream; those reporting normal skin, 1.7 g; those reporting dry skin, 2.0 g. To rule out that the effects were due to differences in skin type rather than color, we performed an additional ANOVA using skin type as well as plate color as predictors. As for the ANCOVAs in the analyses of the popcorn and chip studies, we used sequential sum of squares to remove the effect of skin type before testing that of plate color. The analysis provided evidence for an effect of skin type, $F(2,66) = 3.12$, $p < 0.05$, and again clear support for an effect of plate color, $F(2,66) = 6.1$, $p < 0.01$.

Contrast analysis, all three studies

To evaluate if the pattern of results observed in the three experiments can be accounted by the color difference between foods or cream and the plates (i.e., "contrast" effects), we inspected plots of consumption as a function of colorimetric assessments of contrast. We made a conceptual distinction between achromatic (luminance) contrast and chromatic (color proper) contrast. The first is well defined psychophysically and its relations to visibility are clearly understood. The second is less well defined and implies a model of the perceptual space of colors. As justified in the method section, we choose to measure achromatic contrast using the Michelson ratio, which captures well the relative change in luminance in a center-surround visual display. To measure chromatic contrast, we used the Euclidean distance on the a^*b^* plane as defined in the CIELAB colorimetric model. This distance provides a good approximation to the perceptual chromatic difference between plates and stimuli on the plates, independent of their achromatic intensity. To plot the data for all three experiments jointly, we computed measures of normalized consumption by dividing the original data by the maximum consumption value observed in the relevant experiment.

Figure 2 presents the plot separately for achromatic (left) and chromatic contrast (right). The left plot does not provide evidence for an effect of achromatic contrast. Almost equivalent levels of consumption are observed for the highest and lowest contrast levels. The U-shaped pattern may be interpreted as evidence that intermediate achromatic contrast promotes lower consumption levels, but such a conclusion is ad hoc and is not predicted by any proposal in the literature. Conversely, we note that intermediate achromatic contrasts are systematically associated with red plates, suggesting that the apparent U shape is in fact due to plate color and not to achromatic contrast. The right plot reveals that red plates were systematically associated with the largest chromatic differences with the foods (popcorn and chocolate) and the cream. This is somewhat counterintuitive as the light color of cream and popcorn seems dramatically different from the almost-black color of chocolate chips. As can be easily verified by perusing Table 1, however, this difference is almost entirely accounted for by the achromatic dimension. In chromatic space, the two foods and the cream are in fact quite close to each other. Interestingly, the plot suggests that red plates (and therefore higher chromatic differences) were associated with lower consumption in all three experiments. Fitting a linear regression to the data in Fig. 2, right, did not provide support for the conclusion that the slope is significantly different from zero, $b = -0.002$, $F(1,7) = 1.91$, $p > 0.2$. However, this test cannot be considered conclusive as it is based only on nine datapoints.

Discussion and conclusion

Our first aim in this work was to determine if the effect of red plates on food consumption is robust and can be replicated in a different laboratory. The answer to this question is positive. In two experiments involving two different foods (popcorn and chocolate chips) we observed reduced consumption when the foods were presented on red plates. Although plate colors were related to the amount of food that participants sampled while completing the mock questionnaires, they did not vary as a function of the level of the consciously reported appreciation of the products. This suggests that the effect of plate color operated at an unconscious level and was not mediated by reduced appeal of the products on red plates. That our independent replications were succesful is especially relevant as the original report was surprising and invited a degree of caution. With this regard, we stress that our reported studies were the only ones performed (i.e. we did not keep unsuccesful replications in the file drawer), except for a small-scale preliminary pilot. In this pilot study, we asked participants to perform sensory evaluations of pistachio nuts presented on red or blue randomly-assigned plastic plates (12 participants for each). Interestingly, even in this initial pilot we observed a significant reduction of consumption with the red plates.

A second, specific aim of our work was to evaluate the role of contrast as an alternative account of the effect. As detailed in the introduction, the available studies did not provide sufficient information on this specific issue. To this aim we believe that our paper

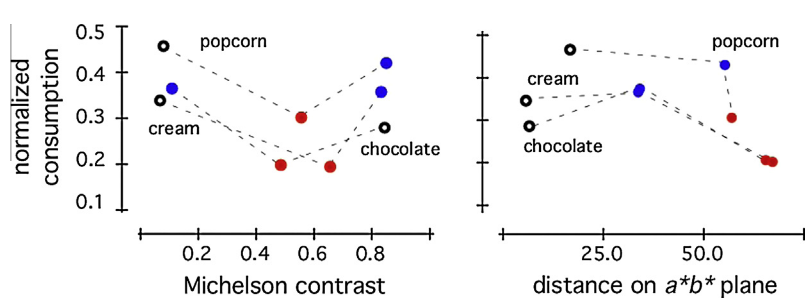

Fig. 2. Consumption of popcorn, chocolate chips, and cream as a function of achromatic (Michelson) contrast and of the chromatic difference with the red, blue, and white plates. Consumption is normalized using the highest value in each experiment. Disk colors identify the colors of the plates in each experiment, and the dashed lines connect plates within the same experiment. Michelson contrast captures the relative change in luminance (achromatic intensity), whereas the distance on the a^*b^* plane captures the chromatic difference ("color contrast") as measured within the CIELAB model. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

makes a conceptual as well as an empirical contribution. At the conceptual level, we have made a well-defined distinction between achromatic contrast (relative change in the intensity of reflected light) and color contrast (perceived difference in the chromaticities of two materials). We believe that further studies of color effects on consumption will need to go beyond qualitative statements about color similarities, and include instead clearly defined definitions of these two types of contrast.

At the empirical level, our findings show that the direction of contrast, however defined, is not important to modulate the effects. We observed equivalent effects of red plates on the consumption of popcorns and of chocolate chips. Technically, the former were luminance increments from the surround to the center of the visual display, whereas the latter were luminance decrements. A large literature on the perception of surface achromatic color suggests that the increment/decrement distinction is relevant to color appearance in a number of ways (see Gilchrist, 2006). Our findings however indicate that this distinction does not affect consumption behavior.

Our findings also provide evidence that the strength of achromatic contrast, independent of its direction, is equally not predictive of consumption. We observed relatively high consumption levels when the contrast between the food and the plate was low, but also when it was high. Conversely, lower consumption was associated with the intermediate contrast levels which, in our experiments, coincided with the red plate conditions. With regard to color contrast, finally, our results are less clear-cut. Although statistical tests of color contrast as a predictor of consumption failed to reach significance, the data in Fig. 2 (right) seem qualitatively consistent with a causal role of color contrast between the plates and the stimuli placed on them. However, given that red plates (and therefore higher chromatic differences) were also associated with lower consumption in all three experiments, the simpler explanation that the reduction in consumption depends on the color of the plate, independent of what is on it, cannot be ruled out. Further investigations involving other types of foods will be needed to resolve this issue.

Finally, a third aim of the present study was to investigate whether the effect of the color red on food consumption generalizes to cutaneous perception and consumption. To this extent, we applied our basic paradigm to a novel situation whereby participants sampled moisturizing cream rather than food, and did so by rubbing it on the hand and the forearm rather than by eating it. Although effects of color on flavor perception, food identification, and now food consumption have been reported by many studies (Auvray & Spence, 2008; DuBose, Cardello, & Maller, 1980; Genschow et al., 2012; Maga, 1974; Piqueras-Fiszman & Spence, 2011; Piqueras-Fiszman et al., 2012; Spence, Harrar, & Piqueras-Fiszman, 2012; Spence et al., 2010; Zampini, Sanabria, Phillips, & Spence, 2007), analogous effects on other sensory processes have remained relatively unexplored so far. Interestingly, our results in the cream study were essentially equivalent to those of the two studies involving food consumption. This result suggests that the effect of red plates on consumption is not limited to eating behavior, and is robust to changes in the mode of presentation of the product as the cream appeared as a single circular mass whereas the popcorns and chocolate chips were scattered on the plates.

Taken together, our results suggest that the effects of red plates on consumption are real and robust, do not depend on a low-level visual property such as achromatic (luminance) contrast, and are not limited to the food domain. Although we also did not observe a significant effect of color constrast, we believe that our results do not definitely rule out color constrast as the visual mechanism behind the effect. Given the current results, however, the weight of the evidence seems to point to an effect of implicit associations as suggested by Genschow et al. (2012). Presumably, red is linked to danger and prohibition by culturally learned or biologically embedded associations, or both. This link elicits avoidance motivation and this in turn predicts an effect of the color red on consumption. This hypothesis is consistent with studies documenting correlations between color preferences and affective responses (Palmer & Schloss, 2010) and with animal studies showing effects of color on food-related behaviors (Khan, Levine, Dobson, & Kralik, 2011).

Numerous environmental factors are known to affect consumption of food (Wansink, 2004). Our findings confirm that color, at least in the conditions of the present experiments, is one of these factors. This in turn provides support to the possibility of using contextual color cues for controlling calorie intake in food consumption and possibly even regulating consumption of non-food substances such as, for instance, cosmetics. Although further research will be needed to evaluate the practical impact of using color for these purposes, the current research suggests that performing such research could be useful and potentially rewarding.

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