

Assessing the Role of Color Cues and People's Beliefs About Color–Flavor Associations on the Discrimination of the Flavor of Sugar-Coated Chocolates

Carmel A. Levitan¹, Massimiliano Zampini^{1,2,3}, Ryan Li¹ and Charles Spence¹

¹Department of Experimental Psychology, University of Oxford, Oxford OX1 3UD, United Kingdom, ²Department of Cognitive Sciences and Education and ³Center for Mind/Brain Sciences, University of Trento, 38068 Rovereto, Italy

Correspondence to be sent to: Carmel A. Levitan, Crossmodal Research Laboratory, Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford, OX1 3UD, United Kingdom. e-mail: levitan@gmail.com

Abstract

We report 2 experiments designed to investigate the effect of people's prior beliefs concerning specific color-flavor associations on their ability to discriminate the flavor of colored sugar-coated chocolate sweets. The participants in our study judged whether pairs of Smarties had the same flavor or not. In our first experiment, the participants either performed the task with their eyes open or else while wearing a blindfold to eliminate any visual cues. We used pairs of Smarties that either did or did not differ in flavor. In making a sighted comparison between red and green Smarties, the participants were more likely to judge them as tasting the same if they believed all non-orange Smarties to be identical in flavor and as different in flavor if they did not hold such a belief. The ability of our participants to discriminate orange Smarties from the red and green Smarties was unaffected by their prior belief that orange Smarties taste different. In a second experiment, participants' ratings of their certainty of there being a difference in flavor between a red and an orange Smartie that either tasted the same or different were affected by their prior beliefs—those participants who expected a difference were more likely to report a difference than those without any such prior expectation. Taken together, these results demonstrate that people's expectations concerning color–flavor associations can modulate their flavor discrimination responses, even for a familiar food product such as Smarties.

Key words: color–flavor interactions, expectations, flavor perception, intersensory conflict, multisensory integration

Introduction

Color is integral to our experience of everyday foodstuffs. People are drawn to certain foods over others not only because of how they taste or smell but also because of how they appear visually (e.g., Stillman 2002). Food color can also sometimes provide an important cue as to whether or not it is safe to eat a particular food (e.g., Wheatley 1973; Clydesdale 1993). Given that specific colors may be associated with particular foods or food properties in the natural environment (e.g., certain colors are typically associated with the ripening of fruits; see Maga 1974; Lavin and Lawless 1998; see also Triplett 1994 and Zampini et al. 2008), it should come as little surprise that color also influences the perception of flavor in various ways.

Over the years, many different researchers have attempted to investigate the role of color on people's perception of flavor (for reviews, see Clydesdale 1993; Spence 2002; Delwiche 2004). For example, in one often-cited study, DuBose et al. (1980) asked participants to identify the fruit flavors present in drinks that incorporated a variety of different color–flavor

combinations (involving the presentation of both “appropriately” and “inappropriately” colored flavored solutions) and found that participants misidentified the flavors of many of the drinks, with their responses often being inappropriately driven by the colors of the drinks. Other researchers have also reported a similar visual modulation of flavor discrimination responses in a variety of different foods and beverages (e.g., Hall 1958; Pangborn and Hansen 1963; Johnson and Clydesdale 1982; Christensen 1983; Hyman 1983; Roth et al. 1988; Zellner and Kautz 1990; Philippsen et al. 1995; Morrot et al. 2001; Zellner and Durlach 2003; Zampini et al. 2007, 2008). Thus, it would appear that color cues can influence or even outweigh the available gustatory and olfactory cues to flavor perception (see also Garber et al. 2000).

These crossmodal influences may arise because of learned associations between color and flavor. Indeed, many researchers have shown that food preferences can be readily learned. For example, in one classic early study, Garcia and Koelling (1966) showed that rats could learn food

aversions in just a single trial provided the associations being taught were plausible. Holman (1974) subsequently showed that flavor preferences could also be easily learned by rats. In terms of flavor perception in humans, Clydesdale (1993) proposed that humans may begin to form associations at birth as specific colors become linked to factors such as sweetness, pleasantness, and acceptability. Furthermore, by synthesizing the results of several different studies, Delwiche (2004) argued that the stronger the association between a color and a flavor, the greater the impact of color on flavor ratings. Lavin and Lawless (1998) also conducted experiments on children and adults in which they obtained sweetness ratings for colored sweetened beverages in order to examine the influence of color and odor on people's sweetness judgments. They found cohort effects which they proposed may have been due to different experiences with products for each age group.

Although certain color–flavor associations, such as those due to ripeness in fruits, are likely to be fairly universal, others may be more context dependent. In particular, different colors are likely to co-occur with different foods in different parts of the world, and so the particular color–flavor associations that arise are also likely to be, at least to a certain extent, culture specific (e.g., Wheatley 1973; Spence 2002). That is, a particular color–flavor pairing that seems congruent to people in the United States may, for example, seem incongruent to those in certain parts of Asia (cf., Demattè et al. 2006). For instance, lemons are typically yellow in color in Europe, whereas in Colombia they are normally dark green in color instead. Thus, it would seem likely that color–flavor associations from repeated coexposure to the colors and flavors in everyday life, and many specific color–flavor associations may be idiosyncratic in nature given the individual differences in diet and exposure.

A classic study reported by Duncker (1939) considered the impact of individual differences in learning such associations. The participants in his study tasted milk chocolate and then white chocolate while blindfolded and then again while sighted. White chocolate was a relatively unfamiliar product at the time the study was conducted. None of the participants noticed any difference in flavor while they were blindfolded. However, 6 of the participants with no prior knowledge of white chocolate reported that the white chocolate in the sighted condition had a different flavor, with 4 of them reporting it as tasting milkier and 2 reporting a weaker chocolate flavor. The only participant who had experienced white chocolate prior to taking part in the study (and who presumably had a previously established learned color–flavor association) reported the chocolates to have the same flavor in all 4 conditions. Despite the methodological limitations of this early study, Duncker's findings nevertheless hint at the possible importance of prior experience and knowledge in modulating color–flavor interactions.

In the present study, we wanted to investigate how individual differences in color–flavor associations may modulate

color–flavor interactions, thus in some sense extending the findings of Duncker's (1939) seminal early study. We used Smarties (Nestlé), a colorful sugar-coated chocolate confectionary, readily available in 8 different colors but only 2 different flavors, as test stimuli: Orange Smarties that have been manufactured for the UK market contain orange-flavored chocolate, whereas all of the other colors contain unadulterated milk chocolate (Nestlé SA 2004). By contrast, Smarties that have been manufactured for other markets all contain unadulterated milk chocolate, no matter what their color. Crucially, this allowed us to present pairs of stimuli which differed in their color but not in their flavor as well as pairs of stimuli which differed in both their color and flavor and that differed in their flavor but not in terms of their color.

We used a same–different paradigm (e.g., Savic and Berglund 2000), whereby, in each trial, the participants had to sequentially taste 2 Smarties and judge whether their flavor was the same or different. We predicted that untrained individuals should indeed recognize the orange flavor as being distinctive. Furthermore, we also predicted that if color does influence flavor identification as has been suggested previously (e.g., Hall 1958; DuBose et al. 1980; Zampini et al. 2007, 2008), then: 1) discrimination accuracy should generally be worse when the participants are blindfolded (and hence have no color information) than when they are sighted; 2) the perceived distinctiveness of the orange flavor should decrease when the participants are blindfolded; and 3) 2 Smarties that are identical in flavor, but differ in color, should be judged as having the same or different flavor depending upon the participant's prior beliefs.

Experiment 1

Methods

Participants

Eighteen untrained undergraduates from the University of Oxford, all nonsmokers, gave their informed consent to participate in the study. All of the participants reported normal or corrected-to-normal vision, normal taste, and normal olfaction (by self-report). They also affirmed that they did not have any medical conditions requiring the monitoring of sugar intake and no known allergy to Smarties. Each participant additionally took the Ishihara (1943) Test for Color Blindness under normal daylight conditions. One participant failed to reach the criterion accuracy of 100% on the 21 test plates and was therefore excluded from the study. Another participant was excluded from the study for failing to complete both of the experimental sessions. The remaining 16 participants (mean age = 20 years), consisting of 8 men and 8 women, were included in the subsequent data analysis. The experiment was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Apparatus and materials

Prior to the first test session, the participants completed a questionnaire (with 2 questions) designed to reveal their familiarity with, and beliefs about, Smarties: 1) How familiar do you consider yourself with Smarties, on a scale from 1 to 5? Please take into account the amount of experience that you have had in tasting Smarties (1 indicating “no experience at all,” 5 being “extremely familiar”). 2) Smarties come in 8 different colors. Do you think you can taste the difference between them? Please give details. The second question was deliberately kept vague (i.e., without particular colors being specified), in order to minimize any possible task demands and experimenter expectancy effects. We used Smarties produced in the United Kingdom as the experimental stimuli. They consist of small milk chocolate pieces in a crisp sugar shell. We used 3 different shell colors in Experiment 1: orange, red, and green. Red and green Smarties are identical except for the coloring of their shell. By contrast, orange Smarties produced for the UK market differ both in terms of the coloring of the sugar coating shell as well as containing orange flavoring in the chocolate itself. Evian mineral water (Danone, France) was provided so that the participants could rinse their mouths out during and between trials as they desired.

Design

A same-different test paradigm was used in order to investigate whether the participants would perceive the differently colored Smarties as having a different flavor. A mixed-measures design was used, with each participant acting as his or her own control in the 2 vision conditions (sighted and blindfolded) and 3 color pairings (orange with red, orange with green, and red with green). Participants' gender and pretest questionnaire responses constituted the between-participants factors.

Procedure

Each participant completed 2 experimental sessions (one sighted and the other blindfolded) on separate days, with the order of presentation of the sessions counterbalanced across participants. The participants were not informed as to which particular combinations of colored Smarties they would taste in either session. Each session consisted of 5 trials with each of 6 possible color pairing sequences (i.e., orange followed by red, red followed by orange, orange followed by green, green followed by orange, red followed by green, and green followed by red), giving rise to a total of 30 randomly ordered trials in each experimental session. The procedure was identical in both sessions, with the sole exception that participants wore an opaque blindfold throughout the blindfolded session, and thus had no visual information regarding the colors of the Smarties that were being presented to them.

Testing was performed under normal daylight conditions. The participants were presented with 2 Smarties in the appropriate sequence in each trial. The participant placed the first Smartie into his/her mouth, tasted the chocolate thoroughly, expectorated the contents into the spittoon provided, and then rinsed his/her mouth out thoroughly with mineral water, once again depositing the contents of their oral cavity into the receptacle provided. The same procedure was repeated for the second Smartie. The timing of the trials was self-paced, so that the interstimulus interval varied across trials. The participants then had to make a verbal “same” versus “different” response regarding whether or not the 2 Smarties tasted the same. The participants also had to rate verbally how confident they were in their judgment on a scale from 1 to 5, with 1 being “least confident” and 5 being “most confident.” The participants' responses were recorded by the experimenter. For the flavor discrimination task, the correct response was different for any trial in which an orange Smartie was presented (because it was always paired with either a red or a green Smartie). Meanwhile, the correct response on those trials in which a red Smartie was paired with a green Smartie was same. No feedback was provided to participants during the experiment regarding the accuracy of their responses. Water was readily available for participants to use between trials, and they were given a short break (terminated by the participant) after every 10 trials.

Results

Response to the questionnaire items regarding participant's familiarity with Smarties revealed that 13 out of the 16 participants (81%) considered themselves to be fairly familiar with Smarties (with a mean self-rating equal or higher than 3). Responses to the questionnaire items regarding participants' belief as to whether different colored Smarties taste different were distinguished for 1) specific references to orange Smarties and 2) generic or specific references to any non-orange Smarties (see Appendix for the entire list of responses). Of the 16 participants, 10 were rated as believing that the orange Smarties were distinctive and 6 were rated as believing that certain non-orange Smarties were distinctive.

The proportion of correct responses on the flavor discrimination task was calculated for each session. A preliminary analysis of variance (ANOVA) conducted on the data revealed no significant main effect of gender on the accuracy of participants' flavor discrimination responses ($F < 1$, nonsignificant [NS]). There was no significant interaction between color pairing (orange with red, orange with green, and red with green) and the order of presentation of the Smarties ($F < 1$, NS). The gender and presentation order factors were therefore disregarded from our subsequent analyses in order to simplify the presentation of the results.

In the first analysis, we evaluated any potential effect of participants' prior beliefs on their flavor evaluation responses for those trials in which an orange Smartie was

presented. The proportion of correct responses for those trials in which an orange Smartie was presented (i.e., an orange Smartie paired with either a red or green Smartie; see Figure 1A) were analyzed using a mixed-measures ANOVA with the within-participants factors of Vision (sighted vs. blindfolded) and the between-participants factor of Belief that orange Smarties taste distinctive (present vs. absent). The analysis revealed a significant main effect of Vision ($F_{1,14} = 17.63, P < 0.001$), with participants responding less accurately (i.e., they were less likely to respond different) when blindfolded (mean proportion of correct responses = 0.78) than when they were sighted ($M = 0.94$). None of the other terms were significant (all $F_s < 1, NS$).

In the second analysis, we assessed whether participants' prior beliefs concerning non-orange Smarties might have influenced their flavor discrimination responses regarding

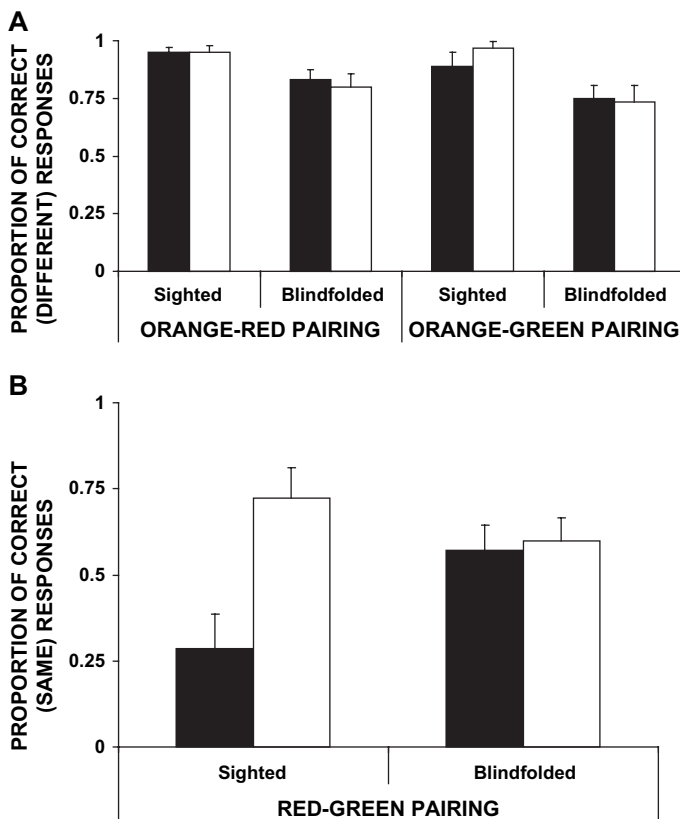


Figure 1 (A) Mean proportion of correct responses (i.e., “different taste”) for those participants who do ($N = 10$; black bars), and those who do not ($N = 6$; white bars), believe that orange-colored Smarties have a distinctive flavor, on those trials where the participants compared an orange Smartie with either a red Smartie or with a green Smartie in Experiment 1. (B) Mean proportion of correct responses (i.e., “same taste”) for participants who do ($N = 7$; black bars), and those who do not ($N = 9$; white bars), believe that certain non-orange Smarties have a distinctive flavor, on those trials where the participants compared a red Smartie with a green Smartie in Experiment 1. Error bars represent the within-participants standard error of the mean based on the ANOVA reported in the text.

the green and red Smarties. The proportion of correct responses for those trials in which a red and green Smartie were presented were submitted to a mixed-measures ANOVA with the within-participants factors of Vision (sighted vs. blindfolded) and the between-participants factor of Belief that non-orange Smarties taste distinctive (present vs. absent). This analysis revealed a significant main effect of Belief that non-orange Smarties taste distinctive ($F_{1,14} = 5.81, P = 0.03$) as well as a significant interaction between the Belief that certain non-orange Smarties taste distinctive and the Vision factor ($F_{1,14} = 8.96, P = 0.01$). This interaction term reflects the fact that the group of participants who believed that non-orange Smarties had a distinctive flavor performed worse ($M = 0.29$) than the group who did not believe this ($M = 0.72$), in the sighted condition (see Figure 1B). Both groups of participants performed with a similar accuracy when blindfolded ($M = 0.57$ for Believers that non-orange Smarties are distinctive and $M = 0.60$ for the other group). What is more, those participants who believed that non-orange Smarties taste distinctive performed significantly better in the blindfolded condition than in the sighted condition.

It has been argued elsewhere that response biases are more likely to influence a participant's performance when they are less certain of their responses (i.e., when their confidence in the correctness of their response is low; e.g., see Soto-Faraco et al. 2004). Therefore, we performed an additional analysis where we only used sighted trials in which participants gave a confidence rating of 3 or higher (resulting in the removal of 21% of the trials). An ANOVA performed on the proportion of correct responses for the remaining trials revealed exactly the same significant effects as reported in the previous analysis (when no trials had been excluded), thus reducing the possibility that a response bias account could explain the effects found in the sighted condition.

We also conducted an analysis to evaluate whether the participants' confidence in their responses changed as a function of them having their eyes open versus being blindfolded. Participants' mean confidence ratings were submitted to a repeated measures ANOVA with the within-participants factors of Vision (sighted vs. blindfolded) and Color pairing (orange with red, orange with green, and red with green). This analysis revealed a significant main effect of Vision ($F_{1,15} = 14.12, P = 0.01$) with the participants being more confident of their responses when their eyes were open. The main effect of Color was also significant ($F_{2,30} = 16.56, P < 0.001$). Participants were more certain of their responses on those trials where an orange Smartie was presented. Finally, the analysis also revealed a significant interaction between the Vision and Color factors ($F_{2,30} = 4.19, P = 0.025$) showing that our participants were more confident of their responses when they could see the chocolates than when they were blindfolded for those trials that included an orange Smartie.

Finally, we performed analyses on the sensitivity of our participants' responses using their confidence ratings to

compute an R-index (see O'Mahoney 1992) for each participant using all of the trials for both sighted and blindfolded conditions. Using R-index as a dependent variable yielded exactly the same pattern of results as those described above.

Discussion

The most important finding to emerge from the analysis of the results of Experiment 1 was that people's beliefs concerning specific color-flavor associations for an everyday food-stuff such as Smarties significantly affected their flavor discrimination responses. Each participant tasted all the possible pairings of orange, red, and green Smarties and judged whether or not a given pair differed in flavor while either sighted or blindfolded. Pretest questionnaire responses indicated that a number of the participants incorrectly believed that certain non-orange (i.e., red and green) Smarties had a distinctive flavor, while others were apparently aware that all non-orange Smarties tasted the same. In the sighted condition, the latter group of participants was significantly more likely to judge correctly that a red-green pairing of Smarties tasted identical in comparison to the first group, who performed at a level that was significantly below chance (i.e., they reported that the red and green Smarties tasted different on the majority of trials; see Figure 1B). In other words, those participants who believed that they would be able to taste a difference between the red and green Smarties did in fact judge the 2 as tasting different far more frequently when compared with the participants who did not hold such a belief.

The results of Experiment 1 also confirm a number of previously established findings concerning the crossmodal influence of color on flavor perception but demonstrated here for the first time using sugar-coated chocolate sweets that were familiar to the majority of the participants in our study. The participants in Experiment 1 were just as accurate in discriminating orange from either red or green Smarties but were significantly less accurate in making same responses when presented with a pair of red and green Smarties. It follows from this that the participants judged the orange Smarties as particularly distinctive in flavor among the 3 colors of Smarties. Our participants' prior belief that orange Smarties tasted different was, however, found to exert no influence on their actual ability to discriminate orange Smarties from the red and green Smarties, thus suggesting that the unique flavor of the orange Smarties was indeed highly distinctive to our participants. The participants were still fairly accurate at discriminating the orange Smarties from other colors of Smartie when blindfolded, but there was a significant decrease in the accuracy of their performance as compared with when they could see the Smarties. However, when the participants were blindfolded, they performed at a level that was no better than chance when presented with 2 objectively identical Smarties. That is, they were unable to confidently assert that 2 identically flavored Smarties actually tasted the same.

Given that each of the participants in Experiment 1 had to evaluate multiple pairs of Smarties, we were concerned that they might have changed their beliefs concerning particular color-flavor associations for Smarties over the course of the experimental session itself. Specifically, we thought that they might have learned, for example, over successive trials that orange Smarties do actually have a distinctive flavor. We therefore conducted a second experiment in which we presented each participant with only a single pair of Smarties so that we could eliminate the possibility that the experiment itself could shape the beliefs that were held by our participants. We also wanted to investigate how participants would respond to orange Smarties when they no longer had a flavor that was distinct from that of the other-colored Smarties and how they would respond to pairs of Smarties that were the same color but differed in flavor.

Experiment 2

Methods

Participants

A total of 336 untrained students attending the University of Oxford (but not necessarily UK nationals) took part in this study, which was conducted at an orientation event for new students. The participants confirmed that they could recognize the colors of the Smarties used in the study and affirmed that they did not have any medical conditions that would contraindicate eating Smarties.

Apparatus and materials

The participants were asked 2 questions designed to reveal their familiarity with, and beliefs about, Smarties: 1) How familiar do you consider yourself to be with Smarties, on a scale from 1 to 5? Please take into account the amount of experience you have had in tasting Smarties (1 indicating "no experience at all," 5 being "extremely familiar"). 2) Smarties come in 8 different colors. Have you ever noticed any colors tasting different? In this experiment, we listed the 8 colors to avoid the possibility of vague responses. We used red and orange Smarties produced in the United Kingdom and in Germany as the experimental stimuli. Whereas the orange Smarties produced in the United Kingdom contain orange flavoring in addition to chocolate, those produced in Germany do not contain the additional orange flavor. The Smarties produced in the 2 countries were not exactly identical but were very similar in appearance.

Design

A same-different test paradigm was used in order to investigate whether the participants would perceive the differently colored Smarties as having a different flavor. A between-participants design was used, with each participant tasting only a single pair of Smarties.

Procedure

Each participant was asked the 2 questions about Smarties and then given a single pair of Smarties to taste. There were 4 possible pairings—1) a red and an orange Smartie that tasted different ($N = 108$), 2) a red and an orange Smartie that tasted the same ($N = 108$), 3) 2 orange Smarties that tasted different ($N = 60$), and 4) 2 orange Smarties that tasted the same ($N = 60$). We chose to test more participants in the red–orange pairings because we divided their responses based upon whether they had a prior belief about the Smarties tasting different, and we wanted to ensure we had a sufficient number of participants in each group; this was not relevant for orange–orange pairings as the participants were unlikely to have had any prior expectation that 2 orange Smarties would differ in taste. The participants were instructed to eat each Smartie, and the timing was once again self-paced. The participants then had to respond by indicating whether: 1) the 2 Smarties definitely tasted the same, 2) probably tasted the same, 3) probably tasted different, or 4) definitely tasted different (see O’Mahoney 1992). The participants’ responses were recorded by the experimenter.

Results

Response to the questionnaire items regarding familiarity revealed that 200 out of the 336 participants (60%) considered themselves to be fairly familiar with Smarties (with a rating of at least 3 out of 5). The participants’ responses to the questionnaire items regarding their beliefs as to whether different colored Smarties taste different are shown in Table 1.

Each response was coded and then scaled to generate a value in the range between 0 and 10, with a score of 0 indicating that the participant rated the pair of Smarties as definitely tasting the same while a score of 10 indicated that they rated the pair of Smarties as definitely tasting different. A mean difference score was calculated for each group of participants. We compared the difference scores for pairs of red and orange Smarties that either tasted the same or else that tasted different. The difference ratings were then subjected to a univariate ANOVA with the between-participants factors of Flavor difference (whether the orange-colored Smartie was flavored orange), and Belief (whether the participant expected the red and orange Smartie to taste different). This analysis revealed a significant main effect of Flavor difference ($F_{1,212} = 74.17, P < 0.001$) with the participants assigning a much higher difference rating to those pairs of Smarties that were flavored differently than to those that were not, just

as one would have expected (see Figure 2). The analysis also revealed a significant main effect of Belief ($F_{1,212} = 9.14, P < 0.005$), with those participants who had a prior expectation that the red and orange Smarties would taste different assigning larger difference scores than those who held no such expectation. There was, however, no significant interaction between the factors ($F_{1,212} = 0.05, P = 0.83$), indicating that, unlike in Experiment 1, the effect of belief was significant regardless of whether there was an actual difference in the flavor of the 2 Smarties or not.

Next, we examined the participants’ ability to detect differences in flavor when both of the Smarties were colored orange. We conducted a t -test to compare the difference scores when the Smarties did and did not taste the same and found a significant difference between the 2 conditions ($t_{118} = -6.68, P < 0.001$), indicating that even in the absence of any distinctive color differences, the participants were able to successfully differentiate between the 2 Smarties.

Discussion

In Experiment 2, the participants either tasted a red–orange pair of Smarties or an orange–orange pair, where one of the pair either did or did not have a distinctive flavor. Based on their questionnaire responses, the participants who tasted a red–orange pair were grouped according to whether their prior beliefs led them to expect that there would be a difference in taste between the red and orange Smarties or not. Those participants who expected there to be a difference reported experiencing the 2 Smarties as more different in flavor than those participants who did not expect there to be any such difference, regardless of whether the Smarties actually had the same or different taste. We also found that participants could reliably detect genuine flavor differences even when the 2 Smarties were both colored orange.

By having a very large number of participants each rate a single pair of Smarties, we were able to eliminate the possibility that their beliefs about Smarties would change over the course of their experimental session (such as if they began to notice that orange Smarties have a distinctive flavor). In Experiment 2, we found that people’s prior beliefs influenced their ability to discriminate between red and orange Smarties, both in the presence and in the absence of an actual flavor difference. This result differs from the findings reported in Experiment 1, where the participants were able to detect the orange flavoring in the orange Smarties whether or not they had a prior belief. One factor that might help to account for this difference in results relates to minor

Table 1 Distribution of responses concerning which colors of Smarties the 336 participants in Experiment 2 expected to taste different

All taste same	All taste different	Red differ	Orange differ	Yellow differ	Brown differ	Green differ	Pink differ	Purple differ	Blue differ	Depends on country
186	5	5	130	2	20	5	0	3	20	1

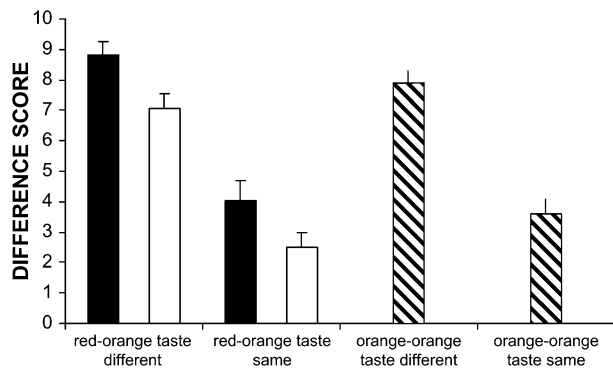


Figure 2 Mean difference scores (0 = definitely taste the same, 10 = definitely taste different) for pairs of Smarties in Experiment 2. Black and white bars indicate responses on the trials with red and orange Smarties for participants who believe that red and orange Smarties do (black) or do not (white) differ in taste. The hatched bars indicate responses to pairs of orange Smarties that either did or did not differ in taste. Error bars represent the within-participants standard error of the mean based on the ANOVA and *t*-test reported in the text.

methodological differences that were present between the 2 experiments. In particular, the participants in Experiment 1 had to taste a large number of Smarties and thus were instructed not to swallow them. In Experiment 2, however, each participant only tasted 2 Smarties and thus they were permitted to swallow them. Thus we cannot rule out the possibility that this methodological difference may have somehow impacted upon our participants' flavor perception as swallowing has been shown to impact odor and flavor perception (e.g., Buettner et al. 2001; Hodgson et al. 2003). Another possibility is that the orange flavoring may have been sufficiently striking that the participants in Experiment 1 might have learned that the orange Smarties contained an added flavoring, thus nullifying the effect of prior expectations. The single trial paradigm used in Experiment 2 reveals that beliefs do matter for flavor discrimination performance.

General discussion

The results of the 2 experiments reported in the present study confirm the hypothesis that food coloring can exert a powerful influence over people's flavor discrimination performance, a finding consistent with previous reports that color cues can influence flavor detection thresholds (e.g., Maga 1974; Johnson and Clydesdale 1982), perceived flavor intensity (e.g., Roth et al. 1988), and flavor identification (e.g., DuBose et al. 1980; Zampini et al. 2007, 2008) in many different everyday foods and beverages.

One issue that is still unresolved is the extent to which the influence of color on flavor discrimination has an underlying perceptual and/or decisional basis (on this point, see Zampini et al. 2007). If viewing the color changed the nature of the gustatory experience itself, then the effect would be deemed perceptual in nature; that is, knowledge of the color might improve the sensitivity of participants' discrimination

of flavor responses by reducing the variability of the flavor signal. Alternatively, according to the decisional account, a participant would have the same gustatory experiences for a given color-flavor pairing no matter whether sighted or blindfolded. Instead of the sensitivity of participants' flavor discrimination responses being changed by the addition of vision, their decision criteria could have been changed instead. If, for a given pair of Smarties, the participant was uncertain as to whether they tasted the same or different, being able to see that they were differently colored would likely bias their response toward making a different response (or same response in the case of a red-green comparison if the participant already knew red and green to be identical in taste). In the case of olfaction, Engen (1972) has presented findings in support of color influencing odor perception through decisional mechanisms, but this does not, of course, necessarily rule out a role for perceptual interactions as well, at least when tested under the appropriate experimental conditions (see Zellner and Kautz 1990).

One possibility to bear in mind here is that a person's beliefs about particular foods tasting different if they have a different color may paradoxically result in them actually tasting different. Analogously, de Craen et al. (1996) reviewed a number of studies showing that color cues influence the effectiveness of medicines as well as placebo pills. Anecdotally, nurses in France have also been reported to use red Smarties as placebo medications on the wards. Although the mechanism behind placebo effects such as these is not as yet well understood, such effects are nevertheless robust (e.g., for a review, see Koshi and Short 2007). It is our contention that if people's beliefs about color and medication can effect their physical states (e.g., resulting in a genuine change in their tolerance for pain, say, or in their, again, ability to sleep etc.), then it would seem conceivable that a person's belief that a certain colored Smartie tasted distinctive (from a Smartie of a different color) might give rise to the effect of it, paradoxically, actually tasting different to that person, despite there being no flavor difference physically present between the 2 Smarties.

The results of the present study therefore build upon a large body of empirical literature suggesting that food color can have a powerful crossmodal influence on people's perception of food flavor. People's beliefs about food color-flavor associations can moderate this influence, and such cognitive influences can be robust and long lasting despite extensive experience with the particular food item concerned. Finally, it is interesting to note that people can maintain such inappropriate beliefs about differently colored Smarties tasting different, despite the objective evidence that people perceive no difference in their flavor, and the fact that they have had extensive previous exposure to the fact that these colors provide no useful information in this foodstuff. Several participants in our second experiment mentioned a specific advertising campaign that had promoted the orange Smarties as being somehow "special." Meanwhile, others

volunteered that they typically ate handfuls of Smarties at a time, and thus had not had the opportunity to assess individual colors of Smartie for their particular flavor. Thus, the process of building up color–flavor associations is not completely straightforward but may be modified by advertising and by specific eating habits.

Color can have a major impact on, for example, the way in which consumers differentiate between food products (Garber et al. 2001, 2003), and this impact may be maximized through the use of effective marketing (cf., Triplett 1994; Wells 2005) to reinforce particular color–flavor associations held in consumers' minds. In this regard, we note with interest Nestlé UK's release of Fruity Smarties, fruit-flavored sweets coated in inappropriately colored shells which present an explicit challenge for consumers to identify the actual flavors used (see <http://www.smarties.co.uk/fruitysmarties.htm>; downloaded on 18 May 2007). Such a product, whose very selling point centers around color–flavor associations, might indeed be considered a good example of the use of food color in enhancing the consumer experience of consuming food, beyond the mere improvement of a food's acceptability.

Appendix

Responses given by each of the 16 participants (P1–P16) prior to the experiment, to the question: “Smarties come in 8 different colors. Do you think you can taste the difference between them? Please give details”.

- P1: Orange Smarties are supposed to taste orange and I think I will be able to taste the difference! Otherwise, they all taste the same. I know nothing about the flavorings used in the different colors of Smarties.
- P2: Orange ones are apparently made of orange chocolate, though I've never stopped to try to tell the difference.
- P3: I think green tastes different. They taste of lime and taste fresher. Some colorings may be derived from natural sources and then reproduced synthetically? I don't know. . .
- P4: I think that only orange Smarties taste very different.
- P5: Orange tastes different. All the rest taste the same.
- P6: I think that I can to a certain extent. I like yellow ones better than blue ones, for example, just because yellow ones have the same color as that of bananas. But I'm not sure if this means that I can tell the difference in the taste between them, it's just that I like some better than others because they remind me of certain flavorings (e.g., banana, strawberry—both are my favourites!). I don't really know much about the flavorings used though.
- P7: Orange Smarties have a distinct flavor. There is some difference with the other colors, e.g., black is bitter, blue sweeter.
- P8: No difference in taste except for orange color.
- P9: Orange ones taste orangey. Blue ones taste better.
- P10: No. It's just coloring. I didn't know they used flavorings.
- P11: I can taste orange ones apart from others. I don't know anything about the flavorings used.

P12: Orange tastes different, but I know they actually add orange flavoring to them—do occasionally find brown and blue to taste slightly different.

P13: No.

P14: They all taste fairly similar to me, but if I were tasting them with the express intention of tasting the difference, I think it would be possible.

P15: I think I can tell that there is a difference but am not confident I could tell which color a Smartie is just from taste.

P16: I think they all taste the same.

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