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The color of emotion: A metric for implicit color associations

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ABSTRACT

Color cues impact the chemosensory perception of foods and beverages. Evidence suggests that color exerts these effects through a link with emotion. In this study, color associations to 20 emotion terms were obtained by having 194 participants use a touch-screen display to select a matching color. The resulting color matches were displayed visually and their coordinates in the $L^*a^*b^*$ system were analyzed statistically. Matching colors were found to differ as a function of emotion, with participants' age and sex somewhat moderating color matches. Color matches were also obtained to nine beverage-related sensory scenarios. The results indicate that consumers have pre-existing expectations regarding the appropriate color for specific flavors and types of drinks. Quantitative assessment of color-emotion associations may help clarify the cross-modal effects of color on taste and smell.

1. Introduction

Consumer expectations play a major role in the sensory perception of food and drink. These expectations may be culturally based or the result of cues provided by the product's packaging and presentation (Piqueras-Fiszman & Spence, 2015; Spence & Piqueras-Fiszman, 2012). The consumer's perception of flavor also depends upon a host of multisensory cues, among them sound, scent, and color (Shankar, Levitan, Prescott, & Spence, 2009; Zellner & Durlach, 2003; see Spence, Levitan, Shankar, & Zampini, 2010 for a review). These sensory factors themselves may be interrelated. For example, smells are associated with specific colors independent of any particular context (Gilbert, Martin, & Kemp, 1996; Kemp & Gilbert, 1997; Maric & Jacquot, 2013). Emotion may mediate the associative links between color and scent (Porcherot, Delplanque, Gaudreau, & Cayeux, 2013; Schifferstein & Tanudjaja, 2004), and between color and music (Palmer, Schloss, Xu, & Prado-León, 2013).

In product design, for example, consumers are presumed to associate colors with specific emotions and mental states. Thus, a single color palette would not be expected to work as well for an energy drink as for a calming herbal tea. Such assumptions remain untested systematically. Does the scientific literature offer any insights into designing for affective impact with color?

How color relates to emotion is the subject of much psychological research, but the results are difficult to marshal for practical use.[1] The reasons for this are both technical and conceptual. As a technical matter, color-emotion data have been gathered with experimental methods that vary widely in precision and scope, as we describe below. To our knowledge, no study to date has used an objective, open-ended method to specify the color that best matches a given emotional stimulus.

Conceptually, the link between color and emotion is complicated by the existence of two different experimental approaches. The first approach asks participants to specify, "what color is associated with emotion *x*?", whereas the second reverses the sequence and asks, "what emotion is associated with color *y*?" Both approaches match colors to emotion-related stimuli, and although the results might appear superficially equivalent, e.g., "angry is red" and "red is angry," these results are not transitive. Thus, red may connote anger, but it may also connote jealousy, irritation,

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[1] In this paper we use the word "emotion" as shorthand to refer to the use of verbal stimuli that contain terms such as "sad," but also moods such as "calm" and even motivational states such as "hungry." We do this advisedly, knowing that some readers might prefer the broader term "affect," and with full appreciation of the historic and philosophical conundrum that the term "emotion" presents to investigators who endeavor to define its bounds, or specify and categorize it operationally (see, e.g., Barrett & Russell, 2009; Fridlund, 2015; Fridlund & Russell, 2006; Russell, 2003, 2015).

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and pride. Conversely, anger may be associated with red but also with black.

Practical application often favors one of these approaches over the other. A product designer honing the emotional appeal of a brand may be free to use the most effective color from an unconstrained palette; in this case the first approach supplies the most relevant results. Alternatively, a designer may need to determine the emotional associations to a brand's existing color scheme. In this case, the second approach is most relevant. Our focus in this paper is the former question, namely "what color is associated with emotion *x*?"

The basic method for answering this question is to present a printed emotion or mood term and ask participants to provide the best-matching color. The color response options used in previous studies are summarized in Table 1, which also categorizes the options as objective or subjective (i.e., physical color samples versus verbal reply), and constrained or unconstrained (i.e., a selected subset of colors versus all available colors). Studies with objective response options are preferable for many reasons, yet it is apparent from Table 1 that every such study has used a limited numbers of colors. Similarly, studies using unconstrained options capture the greatest range of response, but to date such studies have used only subjective responses. Thus, the link between emotion and color has yet to be studied with a color-matching method that is both unconstrained and objective. This technical limitation impedes the psychological study of the relation between color and emotion, and makes it difficult to implement the results in the applied field of sensory design.[2]

Our interest is in developing a method that permits consumers to specify color matches to a wide range of stimuli, including emotional stimuli, in a way that is minimally constrained yet yields precise and quantitative research data. An ideal experimental technique would: (1) allow each participant to select a single best color match from the entire visible spectrum, (2) quantify that color match according to a standardized system, and (3) enable the display of individual data points as well as group summaries. Here we introduce a touchscreen color-selection application that achieves these objectives. In addition, we analyze the data using three standard systems for color classification, and compare the resulting outcomes.

Table 1
Experiment methods used in previous studies to identify colors associated with emotions or mood states.

Study	Color response option	Constrained/ unconstrained	Objective/ subjective
Odbert, Karwoski, and Eckerson (1942)	First color name that comes to mind	Unconstrained	Subjective
Wexner (1954)	Eight sheets of colored art paper	Constrained	Objective
Murray and Deabler (1957)	"	Constrained	Objective
D'Andrade and Egan (1974)	157 Munsell chips	Constrained	Objective
Johnson, Johnson, and Baksh (1986)	"	Constrained	Objective
Cimbalo, Beck, and Sendziak (1978)	Seven colors of crayon	Constrained	Objective
Rader (1979)	Distribute five "points" across 11 color names	Constrained	Subjective
Hupka, Zaleski, Otto, Reidl, and Tarabrina (1997)	Rate 12 color names on six-point scales	Constrained	Subjective
Sutton and Altarriba (2015)	First color name that comes to mind	Unconstrained	Subjective

2. Methods

2.1. Participants

The study included 194 participants: 84 teenagers (42 female, 42 male, ages 13–16 years), 53 young adults (28 female, 25 male, ages 25–35 years), and 57 older adults (27 female, 30 male, ages 36 through 45 years).

Potential participants were recruited by telephone from a prescreened, sensory-study database. To qualify for this study, individuals must have purchased and consumed carbonated beverages within the prior three months. Individuals were rejected if they had participated in a market-research interview of one hour or more within the previous three months; or if they or anyone in their household were employed by an advertising agency, a market research company, a manufacturer or retailer of healthcare products, or the news media. As an incentive and to defray travel expenses, each participant was compensated monetarily. Testing occurred over four consecutive weekdays at a commercial consumer testing facility in suburban New Jersey.

2.2. Stimulus presentation

Testing was conducted with custom software installed on an Apple iPad 2. At the beginning of a test session, the experimenter either specified parameters for a new study (e.g., the downloaded stimulus set, number of trials, stimulus order, etc.), or selected from a list of previously designed studies. At this point, the program began the trials for the next participant. Each participant's dataset was labeled with the study name, numbered consecutively within the study to preserve anonymity during data analysis, and date- and time-stamped. The program presented a new screen for each trial; the screen displayed an emotion term and a prompt for the participant to select a color match using a color wheel and light/dark slider.

The program's on-screen layout was designed to resemble that used by Simner and Ludwig (2012) except that the subject responded directly on the iPad's touchscreen rather than with a keyboard and mouse. With each stimulus trial, the program recorded the RGB (Red, Green, Blue) color space values of the selected color and also calculated their equivalent in the CIE $L^*C^*h°$ (Lightness-Chroma-Hue) color system using the equations provided in Tkalčič and Tasič (2003). At the conclusion of a test session, the program was able to display the results for any test item in the form of a Mondrian in which each square represents the color selected by one participant. The RGB and $L^*C^*h°$ data, along with start/finish time-date stamps and other file-header information, were automatically exported from the program via the iPad's email function in CSV format for ready import into Excel and SPSS for statistical analysis.

2.3. Test procedure

Participants were given an iPad and told they would be completing a self-administered questionnaire. A test administrator was available to answer questions. Once the participant completed the name and sex fields, an initial welcome screen provided the following instructions: "We will describe a mood or emotional situation. We'd like you to pick a color that best represents it. There are no right or wrong answers. Practice using the color circle and brightness slider to pick different colors. When you find one you

[2] Like most previous investigators, we used emotion-related words as stimuli for color matching. We do not know (nor did we intend) that the stimuli evoked in the participants the emotions to which they refer. The stimuli let us demonstrate that participants make emotion-color matches; further research would be needed to determine *why* those matches were made.

like, tap the Begin button to proceed." Text above the circle and slider read "Touch the color circle and move the brightness slider to change colors."

Stimulus items were then presented in a fixed order, one per screen, with the following caption always present as a reminder: "Use the color circle and brightness slider to select a color that best represents the mood or emotional situation. When it looks right, tap Match to enter your choice." Tapping "Match" caused the program to record the subject's color selection and proceed to the next stimulus screen.

2.4. Stimuli

Stimulus items 1 through 20 were emotion terms presented in the format "*I feel x.*" The specific emotion terms were: *alert*, *sad*, *relaxed*, *healthy*, *tired*, *soothed*, *tense*, *energized*, *bored*, *happy*, *hungry*, *angry*, *sensual*, *thirsty*, *calm*, *sleepy*, *anxious*, *romantic*, *irritated*, and *refreshed*.

Stimulus items 21 through 29 were not emotion terms. Rather, they were selected as an attempt to extend the color-matching technique to implicit consumer expectations regarding sensory aspects of beverages. These nine stimuli were beverage-related sensory scenarios, beginning with "*I hear fresh soda being poured*," and "*I smell hot spiced cider*." Subsequent scenarios were in the format "*I taste x*," where the specific items *x* were *sweet iced tea*, *a refreshing melon flavored soda*, *an organic herbal soda*, *a refreshing berry flavored soda*, *a healthy vitamin soda*, *a carbonated energy drink*, and *a refreshing citrus flavored soda*.

3. Results

3.1. Qualitative analyses

The primary results obtained here were Mondrians in which each square represents the color selected by one participant as a match for a particular emotion or sensory trial. Visually, a Mondrian conveys intuitively both the overall consensus of response and the degree of response variation.

Each Mondrian presents the matching colors for a given stimulus as selected by all 194 subjects. Within each Mondrian, individual subjects are arranged in the same sequence; starting from the upper left corner and proceeding left to right, top to bottom, the order is: men (42 teens, 25 young adults, 30 older adults) then women (42 teens, 28 young adults, 27 older adults).

3.1.1. Color matches to emotion terms

The color matches selected by all 194 subjects are presented for each emotion term in the Mondrians in Fig. 1. Visual inspection of Fig. 1 reveals that the color-association palettes vary dramatically across emotion terms. Compare, for example, the dark red and orange palette of *angry* to the bright yellow and green colors of *energized*, and to the black and blue colors of *sad*.

It is also clear from Fig. 1 that emotion terms of similar valence resemble each other in color. Compare, for example, the Mondrians for *angry*, *tense*, *irritated*, and *anxious*, which share a palette of dark red and orange, or those for *romantic* and *sensual* which share bright pink and red.

3.1.2. Color matches to beverage-related sensory scenarios

The matching colors selected by all 194 subjects are presented for each sensory scenario in the Mondrians in Fig. 2. These Mondrians reveal a diversity of color palettes, some of which may reflect the typical colors of marketed beverages, e.g., the dark orange of "*hot spiced cider*" and the pink of "*refreshing berry flavored soda*." Other Mondrians may reflect a mix of consumer expectations regarding beverage color. For example, "*refreshing citrus flavored soda*" includes yellow, orange, and green which may correspond to lemon, orange, and lime flavors, respectively. The non-flavor scenario "*I hear fresh soda being poured*" produced a Mondrian that resembles those for the emotions *refreshed*, *relaxed*, *calm*, and *soothed*.

3.1.3. Summary of qualitative results

By providing a single, best-of-all-possible-options color for each panelist, the raw results speak for themselves. Each Mondrian is a palette representing the colors participants associated with a given emotion term; it shows the trend of the entire study population as well as individual variation. Although we present individual choices in order of the subject's age and sex, these results could be arranged in other ways, e.g., by hue.

3.2. Quantitative analyses

The Mondrians appear to show that participants made clear, non-random associations among colors to emotion terms and, separately, to beverage-related sensory scenarios. These qualitative observations must be verified, however, given the natural tendency to see patterns amid randomness, and the fact that any pattern may simply be due to chance (Chapman, 1967; Chapman & Chapman, 1969; Shermer, 2011). We therefore undertook quantitative analysis of the data displayed in the Mondrians.

3.2.1. Choice of color system for analysis

The color data presented us with two questions of approach: which color system best represents the data, and what statistical method captures their complexity? We began with the raw data. Color choices in our study were recorded on the LCD screen of an Apple iPad 2, which displays and stores color as additive color primaries in the form of RGB [Red, Green, Blue] values. Each value in the RGB triplet ranges from 0 (off) to 255 (fully on). Thus an RGB value of [0,0,0] is absolute black, whereas [255, 255, 255] is the brightest white.[3]

We first considered simply using the untransformed RGB data. Vector differences based on RGB data have been used to analyze test-retest consistency of color choices made from computer screens (Ward, Huckstep, & Tsakanikos, 2006), but to our knowledge raw RGB data have not been used to characterize color choices in the literature on color and emotion.

Colors are expressed as coordinates within a 3-space (defined by the range of all possible [R,G,B]), thus our data must necessarily be treated in multivariate fashion (R values cannot be analyzed separately from G values, etc.). Moreover, because we obtained color matches across a number of stimuli (emotion terms in the first set of trials, and beverage-related sensory scenarios in the second), we required repeated-measures multivariate analyses, within so-called *doubly multivariate* designs (Tabachnick & Fidell, 2013).

RGB data can be converted into values of the $L^*C^*h^\circ$ color system (sample algorithm at http://colormine.org/convert/

[3] The color displayed for a given RGB specification is device-dependent. Apple iPads are produced by several vendors across different production runs and vary to some degree in luminance, hue bias, and overall color gamut. Therefore, identical RGB values sent to matching pixels on two iPads may produce slightly different spectrophotometric color values on the two screens. The 255-level resolution of RGB levels was the result of early iPad models using 8 bits to store each value. Other manufacturers began using 16 bits per color, resulting in a changeover to the enhanced "sRGB" specification for color values. Beginning with the iPad 3, Apple shifted to 24-bit color resolution, a superset of sRGB. Shifting to later-version iPads and sRGB values might have affected our results; they would have offered slightly higher on-screen color gamuts to participants and potentially finer gradations on the touchscreen color-selector. It is doubtful, however, that either would have been noticed by participants or affected the results in any systematic way.

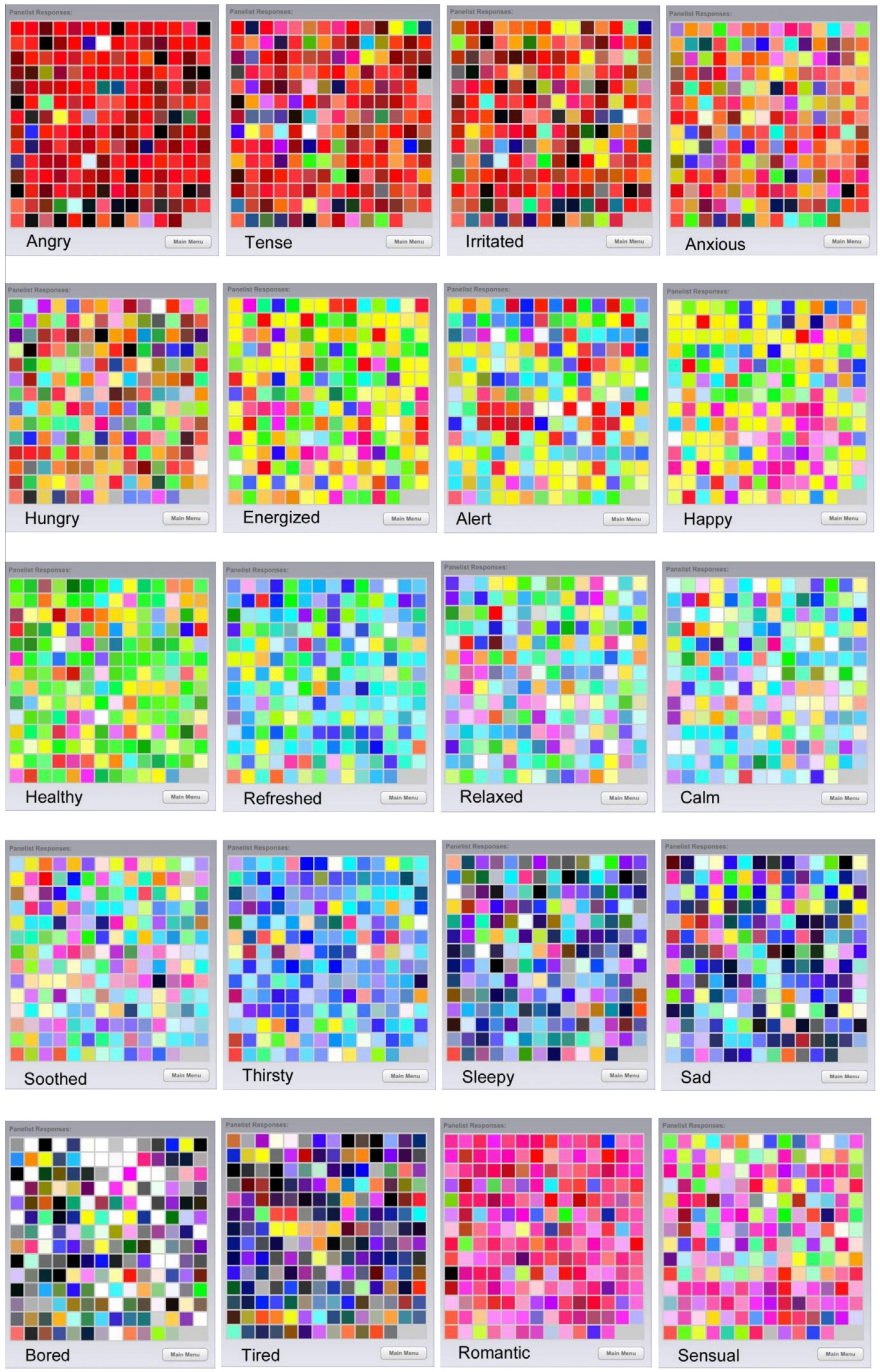

Fig. 1. Color selections by participants (N = 194) for all 20 emotion terms. Color choices are presented as a 194-element Mondrian. In each Mondrian the sequence (starting in the upper left corner and reading each row left to right) is: men (42 teens, 25 younger adult, 30 older adult) followed by women (42 teens, 28 younger adult, 27 older adult).

rgb-to-lch), which some investigators prefer because it is arranged in psychophysically defined intervals and therefore provides a more "perceptually real color space" (Simner & Ludwig, 2012). Two of the L*C*h° coordinates, Lightness (L*) and Chroma (C*), can be analyzed using parametric statistics. Hue (h°), however, is a circular coordinate and therefore unsuitable for parametric statistical inference (Batschelet, 1981). One result is that studies may use parametric statistics on the L* and C* coordinates and

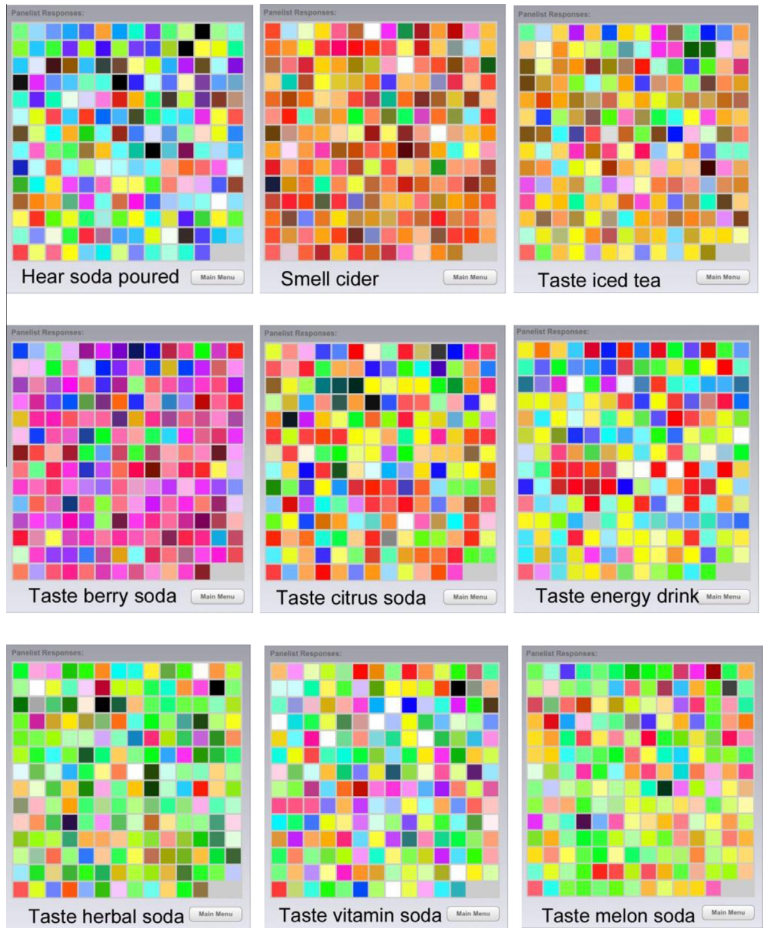

Fig. 2. Color selections by participants (N = 194) for all nine beverage-related sensory scenarios. Color choices are presented as a 194-element Mondrian. In each Mondrian the sequence (starting in the upper left corner and reading each row left to right) is: men (42 teens, 25 younger adult, 30 older adult) followed by women (42 teens, 28 younger adult, 27 older adult).

simply omit h° (e.g., Simner & Ludwig, 2012) or analyze hue separately as a categorical variable (e.g., Ludwig & Simner, 2013). There appears to be no previous instance in which multivariate analysis has been applied to full 3-dimensional color data in the emotion and color literature.

RGB data also can be converted into values of the L*a*b* color system which is based on an opponent-process model of color perception. It consists of Lightness (L*), a Red-Green dimension (a*), and a Yellow-Blue dimension (b*). L*a*b* is preferred in commercial applications such as specifying the color of a liquid perfume or dishwashing detergent. It is unique among the systems we considered in that it delineates a color space that is psychophysically grounded, and all three dimensions are linear, making it suitable for parametric analysis. The L* dimension ranges from 0 (black) to 100 (white). Positive values of a* are red, negative are green; positive values of b* are yellow, negative are blue; on both dimensions 0 represents neutral gray. We therefore chose the L*a*b* system as the focus of our quantitative analyses, with values calculated directly from the RGB data via the algorithm at http://colormine.org/convert/rgb-to-lab. For purposes of comparison, we nonetheless provide results using RGB values and, where possible, L*C*h° values, in the Supplementary material.

3.2.2. Color matches to emotions

L*a*b* values for each of 20 emotional stimuli for the 194 participants were analyzed in a doubly multivariate design using a repeated-measures multivariate analysis of variance, with the triplet L*a*b* values for each trial treated as three multivariate dependent variables, carried across the 20 stimulus trials as a within-subjects factor (Emotion), and with Age (teens, young adults, older adults) and Sex (male, female) as between-subjects factors. Results were computed using the GLM procedure in IBM SPSS Version 23, using a design adapted from Page, Braver, and MacKinnon (2003).

Our primary question for this experiment was whether participants' color choices differ as a function of Emotion. The Mondrians in Fig. 1 seem to indicate that they do. If so, the differences would be discernible in the L*a*b* data. In addressing this question, we first determined whether the L*a*b* data comported with the assumption of multivariate sphericity (i.e., that the differences among all combinations of L*a*b* levels of the 20 Emotion conditions had equal variances; see Page et al., 2003; Tabachnick & Fidell, 2013). Mauchly's test was significant ($p < 0.001$), indicating that sphericity could not be assumed, and that conservative tests of within-subjects effects were required. We therefore present only Greenhouse-Geisser values, which are adjusted for the significant Mauchly's test.

Our hypothesis that color matches to emotion terms were distinctive and nonrandom was supported by the MANOVA results: color matches as measured by L*a*b* values varied by Emotion, F_{adj} $(57,10645) = 65.5$, $p < 0.00001$ (all multivariate adjusted *F*-tests are referred to Wilks' Λ). This effect was modified by several

Table 2
Summary of MANOVA multivariate tests and their univariate decompositions for L*a*b* data, testing hypothesis of non-random matches of color to emotion terms.

*Multivariate tests (L*a*b* triplet data)*			
Emotion			F_{adj} (57,10645) = 65.5, p < 0.00001
Emotion × Sex			F_{adj} (57,10645) = 1.54, p < 0.006
Emotion × Age			F_{adj} (114,10694) = 1.84, p < 0.00001
Emotion × Sex × Age			F_{adj} (114,10694) = 1.54, p < 0.0002
	L*	a*	b*
Univariate tests			
Emotion	F_{adj} (13.9) = 76.0, p < 0.00001	F_{adj} (14.2) = 53.9, p < 0.00001	F_{adj} (14.4) = 48.2, p < 0.00001
Emotion × Sex	F_{adj} (13.9) = 1.2, *n.s.*	F_{adj} (14.2) = 1.8, p < 0.033	F_{adj} (14.4) = 1.1, *n.s.*
Emotion × Age	F_{adj} (27.8) = 1.5, p < 0.034	F_{adj} (28.3) = 1.6, p < 0.032	F_{adj} (28.9) = 2.3, p < 0.0001
Emotion × Sex × Age	F_{adj} (27.8) = 1.1, *n.s.*	F_{adj} (28.3) = 1.9, p < 0.003	F_{adj} (28.9) = 1.2, *n.s.*

interactions which we did not predict. Overall, color matches to Emotion varied by the Sex of the participants [F_{adj} (57,10645) = 1.54, p < 0.006], as well as with their Age [F_{adj} (114,10694) = 1.84, p < 0.00001]. Moreover, the Sex of participants interacted with their Age in affecting their color matches [F_{adj} (114,10694) = 1.54, p < 0.0002].

Having found these multivariate effects, we could decompose them into their univariate constituents. Our predicted effect, that color matches would vary as a function of Emotion, was found to be composed of changes on all three L*a*b* values [all F_{adj} ($\sim$14) $\geqslant$ 48.2, p < 0.00001]. Similar univariate decomposition clarified the nature of the unpredicted interactions we observed. Color-matches to Emotion varied as a function of the participants' Sex, but only in the a* values (i.e., along the Red-Green axis) of their color choices [women showed more positive a* values, or a red shift; F_{adj} (14.2) > 1.80, p < 0.033]. Color matches to Emotion varied with participants' Age, and this Age difference affected all three L*a*b* values [all F_{adj} ($\sim$28) $\geqslant$ 1.55, p < 0.035], but not simply. Moreover, Age affected how participants linked color choices to Emotion depending upon the participants' Sex, but this Emotion by Sex by Age interaction was restricted to changes in the a* values (i.e., to the Red-Green axis) of their color choices [F_{adj} (28.3) = 1.91, p < 0.003]. The complete set of data tables describing these multivariate interactions and their univariate decompositions is provided in Table 2.

3.2.3. Color matches to beverage-related sensory scenarios

Analysis of the beverage-related sensory scenarios followed the same approach used for the emotion-related stimuli. L*a*b* values for each of 9 beverage-related stimuli for the 194 participants were analyzed in a doubly multivariate design using a repeated-measures multivariate analysis of variance, with the triplet L*a*b* values for each trial treated as triplet multivariate dependent variables, carried across the 9 stimulus trials as a within-subjects factor (Beverage), and with Age (teens, young adults, older adults) and Sex (male, female) as between-subjects factors. Results were computed identically.

Mauchly's test was significant (p < 0.00001), indicating as before that multivariate sphericity could not be assumed, and therefore conservative tests of within-subjects effects were required. We therefore present only Greenhouse-Geisser values, which are adjusted for the significant Mauchly's test.

Our primary hypothesis was that color matches to beverage-related sensory scenarios would be distinctive and nonrandom. The hypothesis was borne out by the MANOVA results: color matches as measured by L*a*b* values varied by Beverage, F_{adj} (24,4357) = 32.4, p < 0.00001 (all multivariate adjusted F-tests are referred to Wilks' Λ). The Sex of participants did not influence their beverage-color matches [F_{adj} (24,4357) = 1.3, p = 0.153], nor did their Age (F_{adj} (48,4468) = 0.9, p = 0.677), nor any interaction between Sex and Age (F_{adj} (48,4468) = 1.2, p = 0.208).

Given the overall multivariate effect, we could proceed to discover its univariate constituents. Color matches varied as a function of Beverage for all three L*a*b* values [all F_{adj} (6.9) $\geqslant$ 35.5, p < 0.00001]. The Sex of participants moderated only the L* dimension of their color choices, with women reporting more positive values for Lightness [F_{adj} (6.9) = 2.7, p < 0.009]. Neither the participants' Age, nor any interaction of their Age with their Sex, affected their beverage-color matches. The complete set of data tables describing these multivariate interactions and their univariate decompositions is provided in Table 3.

3.2.4. Summary of quantitative results

Color choices differed as a function of Emotion across all three color dimensions (L*, a*, and b*). Participants' Age affected their color matches, with Age affecting their judgments on all three color dimensions (L*, a* and b*). The participants' Sex independently moderated their matches, but only along the a* (Red-Green) dimension. Likewise, Sex and Age interacted, but only with respect to dimension a*. In any case, as we had no a priori hypotheses with respect to how these factors might impact our matching results, we have no basis for further interpretation.

Similar to the Emotion results, color choices differed as a function of Beverage across all three color dimensions (L*, a*, and b*). The participants' Sex affected the matches, but only on dimension L* (Lightness). Unlike the Emotion stimuli, the participants' Age did not moderate their beverage-color matches. As before, we had no a priori hypotheses with respect to Age and Sex on color matches to beverages, and so we have no basis for further characterization of these results.

4. Discussion

When given the ability to select from an unrestricted array of colors on a computer screen, participants made deliberate, nonrandom color matches to a series of emotion terms. The resulting color palettes are qualitatively distinct and statistically different. It further appears that emotion terms of similar valence were matched to similar colors: the Mondrians for *angry*, *tense*, *irritated*, and *anxious* have dark red and orange in common, while those for *romantic* and *sensual* share bright pink and red (Fig. 1).

Comparison of our results with previous studies is difficult due to methodological limitations in the earlier work (Table 1), e.g., the use of constrained and/or subjective color response options. One study by Wexner (1954), however, provided summaries that allow comparison to ours. In her study, subjects matched "mood tones" (one to four emotion words) to one of eight colors presented as sheets of colored construction paper. Her "despondent, dejected, unhappy, melancholy" mood-tone was matched predominantly to black (chosen by 28% of subjects) and brown (28%), followed by purple (12%) and blue (12%). This result aligns reasonably well with our Mondrians for the emotion terms *sleepy*, *sad*, *bored*, and

Table 3
Summary of MANOVA multivariate tests and their univariate decompositions for L*a*b* data, testing hypothesis of non-random matches of color to beverage-related sensory scenarios.

*Multivariate tests (L*a*b* triplet data)*			
Beverage			F_{adj} (24,4357) = 32.4, $p < 0.00001$
Beverage × Sex			F_{adj} (24,4357) = 1.3, $p = 0.153$
Beverage × Age			F_{adj} (48,4468) = 0.9, $p = 0.677$
Beverage × Sex × Age			F_{adj} (48,4468) = 1.2, $p = 0.208$
	L*	a*	b*
Univariate tests			
Beverage	F_{adj} (6.9) = 35.5, $p < 0.00001$	F_{adj} (6.9) = 51.8, $p < 0.00001$	F_{adj} (6.9) = 43.6, $p < 0.00001$
Beverage × Sex	F_{adj} (6.9) = 2.7, $p < 0.009$	F_{adj} (6.9) = 1.3, *n.s.*	F_{adj} (6.9) = 0.8, *n.s.*
Beverage × Age	F_{adj} (13.9) = 0.7, *n.s.*	F_{adj} (13.9) = 0.6, *n.s.*	F_{adj} (13.8) = 0.9, *n.s.*
Beverage × Sex × Age	F_{adj} (13.9) = 0.9, *n.s.*	F_{adj} (13.9) = 1.1, *n.s.*	F_{adj} (13.8) = 1.4, *n.s.*

tired (Fig. 1). Wexner's "excited, stimulating" mood tone was matched mainly to red (64%), and more distantly to yellow (13%) and orange (12%). Compared to our Mondrians for the similar emotion terms *alert* and *energized*, Wexner's subjects placed more emphasis on red, but the two sets of results are broadly compatible. Finally, Wexner's "cheerful, jovial, joyful" mood tone was associated with yellow (43%), followed by red (21%), and then by orange (15%), green (12%) and blue (7%), which comports with our Mondrian for *happy*. It appears that allowing participants to select matching colors freely yields results that resemble those found under more constrained experimental conditions.

In addition to characterizing emotion terms, we extended the present color-association method to address implicit consumer expectations regarding sensory aspects of beverages. We did this by having participants match colors to beverage-related sensory scenarios. The resulting matches covered a range of color palettes (Fig. 2); statistical analysis of the underlying color data revealed differences across the scenarios. Our results indicate that pre-existing expectations about beverage color can be elicited based on only a verbal description of flavor or style: for example, "I taste a refreshing berry flavored soda" is matched to pink. These implicit color expectations may alter how consumers respond to actual beverages, given that the objective color of food or beverage influences flavor perception (see Clydesdale, 1993, and Delwiche, 2004, for reviews). Future research with our method could explore consumer expectations regarding appropriate colors for novel flavors and formulations in candies and snack foods, as well as beverages. Our method could also be used to design primary and secondary packaging for such products.

Our approach to statistical analysis of color data is a departure from the previous literature. We took the novel step of using doubly multivariate MANOVA to examine all three L*a*b* color parameters simultaneously. (For purposes of comparison, we ran the same analysis using L*C*h° and RGB data; see results in the Supplementary material.) The comparable L*C*h° color system has been used in color-emotion studies but investigators have struggled to find an appropriate form of statistical analysis for the circular distribution of the hue dimension. As a result, it has been omitted from analysis (Simner & Ludwig, 2012; Ward et al., 2006), reduced it to a category-level analysis (Ludwig & Simner, 2013), or replaced with an ad hoc work-around (Palmer et al., 2013). In each case, investigators failed to make full use of the data, even though circular statistical methods are available to characterize hue in univariate analyses; see the Supplementary material.

Our statistical analysis showed that matching colors differed significantly as a function of emotion. It also revealed that those matches were moderated slightly and nonsystematically by a participant's Sex and Age. These differences are intriguing, but with no a priori hypotheses to guide us, we are unable to explore these effects further with the current data set. Gender differences in color preference are not always consistent and may be confounded by other variables such as age and geography. Future research with our method could focus on gender differences in preference for achromatic colors (Guilford & Smith, 1959), for shades, tints, and hues (McInnis & Shearer, 1964), and for chroma (Plater, 1967).

Another promising avenue for further research would be to compare dimensions of emotion (intensity, valence, etc.) with dimensions of color space. One could ask, for example, whether intensity of rated emotion tracks color saturation or lightness (Meier, Robinson, & Clore, 2004). One could also examine whether men and women (or participants of different ages) differ in how they apply color dimensions to dimensions of emotion (Russell, 2003).

We find two main advantages to our method of allowing participants unconstrained color choices on a touchscreen device. It provides precise, quantitative specification of any participant's selected color, and it allows display and sorting of all selected colors across trials and participants. The latter advantage is of direct utility in product development: designers are happy to work from a Mondrian, whether it expresses consumer perceptions of a targeted emotional positioning or the optimal color for a beverage with a specific flavor.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foodqual.2016.04.007.

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