What Color is that Smell? Cross-Cultural Color-Odor Associations

Carmel A. Levitan (levitan@oxy.edu)
Department of Cognitive Science, Occidental College
1600 Campus Road, Los Angeles CA 90041, USA

Jiana Ren (jiana.ren@hotmail.com)
Division of Human Nutrition, Wageningen University
P.O. Box 8129, 6700 EV Wageningen, Netherlands

Andy T. Woods (andy.woods@xperiment.mobi)
Xperiment, chemin I.-de Montolieu 177
1010 Lausanne, Switzerland

Sanne Boesveldt (sanne.boesveldt@wur.nl)
Division of Human Nutrition, Wageningen University
P.O. Box 8129, 6700 EV Wageningen, Netherlands

Jason S. Chan (chan@med.uni-frankfurt.de)
Institute of Medical Psychology, Goethe Universitaet Frankfurt am Main
Senckenberganlage 31, 60325 Frankfurt am Main, Germany

Kirsten J. McKenzie (kirsten.mckenzie@nottingham.edu.my)
School of Psychology, University of Nottingham Malaysia Campus
Jalan Broga, 43500 Semenyih, Selangor Darul Ehsan, Malaysia

Michael Dodson (michaelernest90@gmail.com)
Department of Cognitive Science, Occidental College
1600 Campus Road, Los Angeles CA 90041, USA

Jai Levin (jaialexanderlevin@gmail.com)
Department of Cognitive Science, Occidental College
1600 Campus Road, Los Angeles CA 90041, USA

Xiang Ru Leong (khyx2lxr@nottingham.edu.my)
School of Psychology, University of Nottingham Malaysia Campus
Jalan Broga, 43500 Semenyih, Selangor Darul Ehsan, Malaysia

Jasper J.F. van den Bosch (jasperb@uw.edu)
Institute for Learning and Brain Sciences, University of Washington
1715 Columbia Road N, Seattle WA 98195, USA

Abstract

People can consistently match to odors to colors, and within a culture, there are similarities in color-odor associations. These associations are forms of crossmodal correspondences. Recently, there has been discussion about the extent to which these correspondences arise for structural reasons (e.g., an inherent mapping between color and odor), statistical reasons (e.g., covariance in experience), and/or semantically-mediated reasons (e.g., stemming from language). The present study probed this question by testing color-odor correspondences in 6 different cultural groups (Dutch, Dutch residing-Chinese, German, Malay, Malaysian-Chinese, and US residents), using the same set of 14 odors and asking participants to make congruent and incongruent color choices for each odor. We found consistent patterns in color choices for each odor within each culture, and variation in the patterns of color-odor associations across cultures. Thus culture plays a role in color-odor crossmodal associations, which likely arise, at least in part, through experience.

Keywords: Crossmodal; color; olfaction; culture

Introduction

Would a rose smell as sweet if it were blue? Perhaps not; color plays an important role in recognizing odors and congruent color-odor combinations are rated as more pleasant than incongruent combinations (Zellner, Bartoli, & Eckard, 1991). Colors and odors can be consistently matched across participants (e.g., Gilbert, Martin, & Kemp, 1996; Demattè, Sanabria, & Spence, 2006; Maric & Jacquot, 2013); for instance, caramel tends to be most commonly associated with brown. Color influences odor identification, discrimination, intensity, and even pleasantness (see Zellner, 2013 for a thorough review). Thus a crossmodal correspondence between color and odor exists.

Crossmodal correspondences can take different forms. Spence (2011) distinguishes between three kinds of correspondences: structural, statistical, and semantically mediated. Structural correspondences can occur due to neural connections (e.g., if stimuli in different senses share a feature such as intensity). Statistical correspondences are learned, and occur when two stimulus dimensions are routinely correlated in the environment. Semantically-mediated correspondences arise due to language (e.g., "low" for elevation and pitch). The type of crossmodal effect has implications for the perceptual consequences of the correspondence; semantically-mediated correspondences are decisional, but structural and statistical correspondence can lead to perceptual or decisional effects. For color-odor associations, both perceptual and semantic factors seem to play a role; color brightness correlates with perceptual attributes of odors (odors that are more irritating, intense, and unpleasant are associated with brighter colors) and semantic attributes (more familiar and identifiable odors are associated with more saturated colors), though hedonics are also important (Stevenson, Rich, & Russell, 2012).

Cross-cultural comparisons allow some insight into how correspondences might emerge. Structural correspondences might be highly idiosyncratic (in the case of synesthesia) or universal (if they reflect an underlying neural mechanism common to all people). Some statistical correspondences are also likely to be universal (e.g. larger objects tend to have lower resonant frequencies) but others may be less universal if environments are likely to differ. Finally, semantically mediated correspondences are more context dependent; as language influences these associations, different cultures may experience different crossmodal associations.

Comparing different studies that used similar stimuli could provide insight into this question. Many studies have shown that yellow and lemon correspond, but this could easily be learned and could be mediated by recognition of the odor. Potential evidence for structural correspondences (in the universal sense) between color and odor come has come from cases in which colors are reliably associated with odors where there is not a likely history of learning, such as for almond (Spector & Maurer, 2012). In that study, conducted in Canada, almond was significantly associated with red (and also with purple and gray). If the correspondence was not learned, then this result would support the notion of a structural correspondence. However, the red-almond association is not universal, as in an Australian sample, almond was associated with blue (Stevenson et al., 2012). But because there was variation in the odors used (as well as their concentration) and the ways in which the color matches were obtained (e.g. verbal report of color, matching color chips, indicating a point on a color wheel) and analyzed, procedural, rather than cultural, factors may underlie differences in results. Thus comparison of different studies cannot fully address this question of universality; studies explicitly designed to examine cultural factors can rule out these procedural differences.

Cultural differences in odor perception have been identified. In the US, anise, wintergreen, and cinnamon odors are associated with sweets; in France, they are considered medicinal; and in Vietnam they are classified as floral but associated with traditional medicine (Chrea, Valentin, Sulmont-Rossé, Ly Mai, Hoang Nguyen, & Abdi, 2004). Culturally-specific emotional experiences with particular odors may explain differences in how pleasant the odors are perceived to be; wintergreen has been rated as very pleasant in the US, where it has been associated with candy but as very unpleasant in the UK, where it has been associated with medicine (Herz, 2005). Studies of these cultural differences in odor preferences have been systematically investigated since Pangborn, Guinard, & Davis (1968) studied 16 different groups found that the patterns of odor preferences could be clustered into distinct groups (e.g. all 7 European countries in their sample clustered together) and that both country and ethnic origin influenced liking of particular odors; for instance, ethnic Taiwanese people living in California showered similar preferences to both non-Taiwanese Californians and to Taiwanese people living in Taiwan (Pangborn, Guinard, & Davis, 1968). Subsequent studies have found that people in different cultures even rate the intensity of many odors differently (Ayabe-Kanamura, Saito, Distel, Martínez-Gómez, Hudson, 1998; Chrea et al., 2004; Ferdenzi, Roberts, Schirmer, et al., 2013). As intensity evaluations do not require judgement of identity or pleasantness of the odors, these differences in perceived intensity are particularly noteworthy; decisional factors are less likely to come into play for intensity and thus these differences may be more likely to be perceptual in nature.

Culture's influence on color perception is more controversial. Color names seem to be near universal, but there are some cultural differences in these names; color names in turn can influence perception, though the effect may be stronger in the right visual field than in the left (see Regier & Kay, 2009 for a review). For instance, Russian speakers use different terms for light and dark blues, and are faster at distinguishing shades of blue that cross their linguistic boundary than distinguishing shades that do not (English speakers are not faster at distinctions that cross the Russian boundary). When a spatial interference task is added, the cross-boundary advantage persists for Russian speakers but when a language interference task is added, the cross-boundary advantage disappears (Winawer, Witthoft, Frank, Wu, Wade, & Boroditsky, 2007). Thus the perceptual differences seem dependent on access to language as they are semantically mediated.

The present study compares color-odor associations in participants from different cultural backgrounds, using odors that occur across cultures and using a non-verbal task. If these associations are universal, they are unlikely to be semantically mediated, but if they differ systematically by group, then the crossmodal correspondence between color and odor cannot be structural. The closest cross-cultural study to be done in this area asked British and Taiwanese participants to look at pictures of colored drinks and state what flavor they would expect to experience; that study found systematic differences in expectations, such as brown drinks being associated with cola in the UK and grape in Taiwan (Shankar, Levitan, & Spence, 2010). Those results are likely due to different patterns in beverage consumption in those nations, which could lead to a statistical or a semantic correspondence. Our study uses actual odors and asks participants to select the most congruent and incongruent colors to systematically map out the pattern of association for each group.

Our goal is not just to find the single color most strongly associated with an odor, but instead to map color-odor associations across a wider palette of colors. Summary statistic approaches based on the univariate frequency of a chosen color ignore more subtle interactions with weaker associated colors, or opposing colors. Instead, a multivariate approach is employed to take into account groups of colors, such as bright colors, pastel colors, warm versus cold colors, without explicitly defining these categories.

We choose to apply a representational similarity analysis (Kriegeskorte et al., 2008a) to determine how a distribution of congruent and incongruent colors represents various odors, and the degree to which cultures are similar or differ in their patterns. This technique has been successful in neuroimaging studies comparing physically distinct data, such as semantic categories in monkey and human object areas (Kriegeskorte et al., 2008b).

Our approach allows us to compare color-odor associations, both for specific odors and for the pattern of color-odor associations across cultures. Consistent associations within a culture but differences in patterns across cultures would demonstrate that color-odor associations are not simply structural, but that they are mediated by statistical or semantic experiences.

Methods

Design

Six different populations of participants completed the same task of selecting colors that were the most and least consistent each of 14 different odorants. Culture was a between-participants variable. Odor and consistency /inconsistency were within-participant variables.

Participants

A total of 122 untrained participants from 6 populations were recruited: Dutch, Netherlands-residing Chinese, German, Malay, Malaysian-Chinese, and the US. Dutch and Netherlands-residing Chinese participants (20 of each group) were tested in the Netherlands. Twenty German participants were tested in Germany. Malay and Malaysian-Chinese participants (20 of each group) were tested in Malaysia. 22 US participants were tested in the US. The Dutch resident-Chinese participants were native Chinese people who had resided in the Netherlands for less than 2 years; all other participants had grown up in the country in which they were tested. All participants were healthy volunteers who reported a normal sense of smell and no history of olfactory impairments or current respiratory complications (e.g. colds or allergies). Participants received extra credit in coursework (in Malaysia and the US), cash remuneration (€10 in Germany; €5 in the Netherlands), or chocolate/fruit (in Malaysia) for their participation. Each of the test sites complied with local requirements for ethical treatment of human participants.

Materials

Fourteen odorants were embedded in odor pens. Odorants were originally used for industrial research and were designed to typify the following descriptions: burnt, candy, fish, flower, fruity, hazelnut, meat, musty, plastic, rice, soap, vegetable, vinegar, woody. The specific odors were selected as they were likely to be common across cultures and were easily discriminable. 36 colors, derived from the 32 used in the Berkeley Color Project (Palmer & Schloss, 2010) with the addition of white, light gray, dark gray, and black were randomly arranged for each trial as in Figure 1. The visual stimuli were presented through the Xperiment software package (version 0.0.12; www.xperiment.mobi) either on an Android phone (HTC Desire Z, Android™ 2.2 (Froyo) with HTC Sense™) in the Netherlands or on an iPod touch 3rd Generation in Germany, Malaysia, and the US. (A control experiment found no significant difference in color associations using the different devices.)

Procedure

Participants were given each odor pen one at a time, in random order. Participants indicated the 3 most congruent and 3 most incongruent colors for each pen by selecting those colors on screen; no verbal labels for color or odor

Figure 1: Color choices. 36 colors were arranged in random order for each trial.

were introduced, as we did not wish to activate any semantic associations. We asked participants to select both congruent and incongruent colors as it had been previously used to successfully probe associations with color and music (Palmer, Schloss, Xu, and Prado-León, 2012). Participants were allowed to control their sniffing within each trial, and there was a minimum of a 20 sec. pause between each pen.

Analyses

For each odor, one pattern of choices was compiled, pooling choices from all participants of each group. A color pattern consists of 72 values; two for each of the 36 colors participants could choose; one for the number of congruent and one for the number of incongruent choices. Separate color patterns were made from each of the population samples. For each odor within each culture, we calculated the chi-square associated with the pattern of congruent and incongruent color choices.

To quantify the similarity structure, or isomorphism, of odor-color associations within a culture, we created one representational dissimilarity matrix (RDM; Kriegeskorte et al., 2008) for each population. The RDM has as many rows and columns as there are odors, and each cell in the matrix stands for the dissimilarity between the color-pattern of the odors in the respective row and column. The diagonal of the matrix therefore contains only the value of 0 for perfect dissimilarity of an odor's color-pattern with itself. The dissimilarity was defined as 1 - correlation between the two patterns (Pearson's r).

To quantify the difference between cultures, the second-order isomorphism was calculated as the pair-wise dissimilarity between the culture-specific RDMs, compiled as one inter-culture RDM.

Results and Discussion

Figure 2 depicts the most frequently selected congruent color matches for each odor within each culture. For instance, the fruity odor tended to be associated with pink and red colors, while the musty odor was more associated with browns and oranges. Each of the 14 chi-square values within each of our six groups was statistically significant. Chi-square values ranged from 35.6-41.2, p all below 0.0002. (A Bonferroni corrected cutoff value for significance for the 84 comparisons would result in a threshold for significance of 0.0006.) This confirms that, within each group, there were consistent patterns of color choices for each odor. This result is consistent with those of other studies that only had participants make congruent matches (e.g., Gilbert, Martin, & Kemp, 1996; Demattè, Sanabria, & Spence, 2006; Maric & Jacquot, 2013)

Because we wanted to better understand the patterns of color choices (including both congruent and incongruent choices) for each odor, we calculated the RDMs within each culture, shown in Figure 3. This allows us to take advantage of potential similarities between colors and odors without presupposing a particular representation of those similarities. Within the US, for instance, clusters of odors that had similar patterns of color choices were fruity, flower, and candy; hazelnut, musty, burnt, vinegar and rice; and meat, woody, and vegetable. We also calculated RDMs using only the congruent choices, and found that they were not as successful in finding similarities in patterns of color-odor choices; while this may be in part due to a reduction in data and thus in statistical power, we believe that the incongruent choices are important for uncovering the underlying color-odor space.

We then computed the cross-culture RDM shown in Figure 4 by comparing the overall color-odor associations for each color. We had expected that, if some differences between cultures were to emerge, geographical and cultural similarities would lead to similar patterns as in Pangborn et al.'s study (1998); thus we had predicted that German and Dutch choices would be quite similar and that Malaysian-Chinese choices would be similar to those of both Malay and Netherlands-residing Chinese. None of those

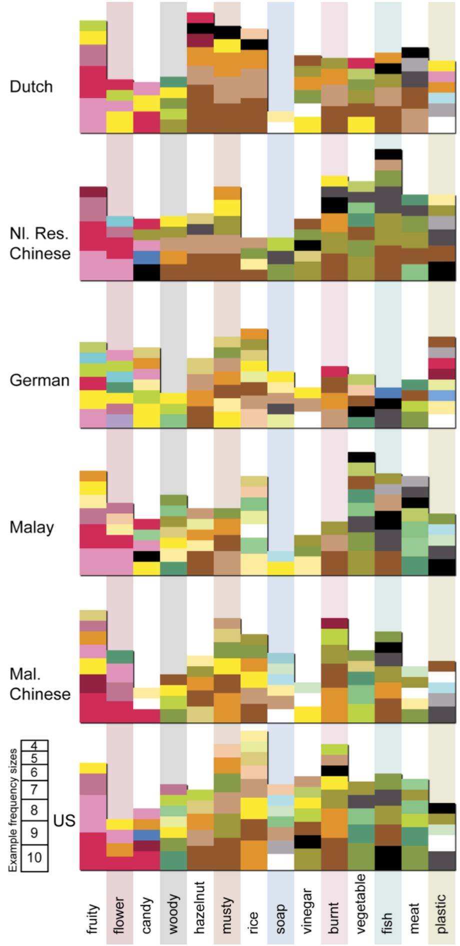

Figure 2: Color congruency for each odor in each culture. Colors per odorant per country are ordered by frequency (most frequent are shown lowest on their respective y-axis). Frequency is represented by the height of each color box; the box on the right of the figure shows the height a given box must be for their to be 10,9,8 etc. ratings of that color for a given odorant. Background bars are colored to help differentiate rows.

predictions were supported by the data. The most similar color-odor associations were between the USA and Germany and between Germany and Malaysia. The largest differences were between Malay and Netherlands-resident Chinese, and between Dutch and Malaysian-Chinese, and the Malay also differed notably from the Dutch and the Malaysian-Chinese. Overall, the USA participants showed the most similarities to other cultures while the Malay participants were the most different from participants in other cultures. The differences could be due to patterns in dietary habits (which differ, perhaps for geographical and historical reasons, between Germany and the Netherlands,), the role of fragrance in each society, or other social factors. Chinese students who choose to study in the Netherlands, for instance, might be living in very different "olfactory" worlds from both Dutch and Malaysian-Chinese individuals.

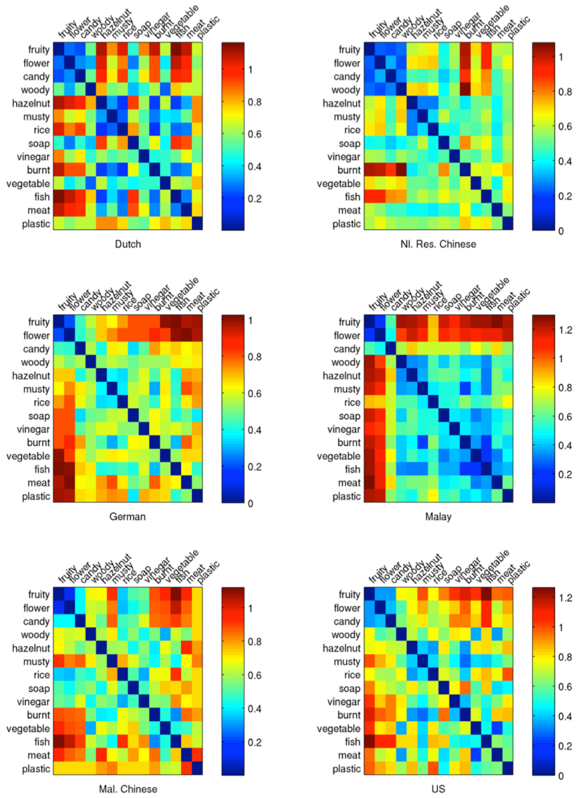

Figure 3. Representational Dissimilarity Matrices (RDM) for each group. Both axes of each represent the 14 odors. Each cell in the matrix indicates the degree of dissimilarity between the color-patterns of the respective odors in that row and column. The dark blue diagonal indicates perfect similarity of the odors with themselves. The representational geometry, or the spatial configuration of clusters of high and low dissimilarities, shows differences and commonalities in each culture.

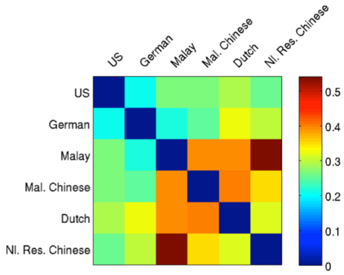

Figure 4. Representational Dissimilarity Matrix comparing cultures. Both axes represent the 6 cultures. Each cell in the matrix indicates the degree of dissimilarity between the respective cultures' odor representation geometry.

The cross-cultural results indicate that color-odor associations – while fairly consistent within a culture – differ across cultures. This pattern argues against the notion that color-odor associations are structural, as structural correspondences would be largely universal. Instead, the results favor statistical or semantically-mediated learning of color-odor correlations.

While it is possible that our results are due to semantic differences, we attempted to minimize effects of language by selecting odors that were relatively general (e.g., fruity rather than strawberry, vegetable rather than broccoli) and we created an interface and procedure that was relatively non-verbal. Moreover, people's ability to label odors is "astonishingly bad" (Yeshurun & Sobel, 2010; see also Lawless & Engen, 1977), though this itself may be culturally specific (Majid & Burenhult, 2014; Wnuk & Majid, 2014). Further research could tease out the effect of language by asking some participants to identify the odor before making color choices and exploring how color choices differ as a result of identification, though this would necessitate a very large number of participants. Such a study would also allow us to determine whether the odors are cuing particular objects, which in turn cue colors, or whether the color-odor associations are mediated by another factor, such as emotion, or by perceptual correspondences.

We also conducted analyses in CIE-Lab color space, to look for patterns in the selected colors for each odor (e.g., whether certain odors were associated with colors of a particular luminance). However, because of how our colors were distributed in the color space, averaging resulted in similar results for all odors. Future studies could better probe the nature of the perceptual correspondences between colors and odors by obtaining intensity and valence ratings of the colors and odors and directly testing how color-odor matches change with these parameters across cultures.

Associative learning influences odor perception; for instance, odors that have been paired together are later judged more similar (Stevenson, 2001) and odors that have been paired with sucrose are later judged to smell sweeter (Stevenson, Boakes, & Prescott, 1998). Odors can even become associated with emotions which in turn shape behavior (Herz, Schankler, & Beland, 2004). Thus it is plausible that color's many effects on odor (Zellner, 2013) also arise via associative learning. In conclusion, we have shown that color-odor associations are robust within a culture, but that there are substantial cross-cultural variations. This is consistent with the notion that these associations are learned through experience.

Acknowledgments

Financial support was provided by an Occidental College Richter-ASP Grant, by the Ready Mind Project (I-LABS), and by the Hessian initiative for the development of scientific and economic excellence (LOEWE Neuronal Coordination Research Focus Frankfurt). Unilever provided the olfactory stimuli.

References

Ayabe-Kanamura, S., Saito, S., Distel, H., Martínez-Gómez, M., & Hudson, R. (1998). Differences and similarities in the perception of everyday odors. A Japanese-German cross-cultural study. *Annals of the New York Academy of Sciences*, *855*, 694-700.

Chrea, C., Valentin, D., Sulmont-Rossé, C., Ly Mai, H., Hoang Nguyen, D., & Abdi, H. (2004). Culture and odor categorization: agreement between cultures depends upon the odors. *Food Quality and Preference*, *15*(7), 669-679.

Demattè, M. L., Sanabria, D., & Spence, C. (2006). Cross-modal associations between odors and colors. *Chemical Senses*, *31*(6), 531-538.

Ferdenzi, C., Roberts, S. C., Schirmer, A., Delplanque, S., Cekic, S., Porcherot, C., ... & Grandjean, D. (2013). Variability of affective responses to odors: culture, gender, and olfactory knowledge. *Chemical Senses*, *38*(2), 175-186.

Gilbert, A. N., Martin, R., & Kemp, S. E. (1996). Cross-modal correspondence between vision and olfaction: the color of smells. *The American Journal of Psychology*, 335-351.

Herz, R. S. (2005). Odor-associative Learning and Emotion: Effects on Perception and Behavior. *Chemical Senses*, *30*(1), i250-i251.

Herz, R. S., Schankler, C., & Beland, S. (2004). Olfaction, emotion and associative learning: effects on motivated behavior. *Motivation and Emotion*, *28*(4), 363-383.

Kriegeskorte, N., Mur, M., and Bandettini, P. (2008a). Representational similarity analysis - connecting the branches of systems neuroscience. *Frontiers in systems neuroscience, 2*.

Kriegeskorte, N., Mur, M., Ruff, D. A., Kiani, R., Bodurka, J., Esteky, H., Tanaka, K., and Bandettini, P. A. (2008b). Matching categorical object representations in inferior temporal cortex of man and monkey. *Neuron, 60*(6):1126-1141.

Lawless, H., & Engen, T. (1977). Associations to odors: interference, mnemonics, and verbal labeling. *Journal of Experimental Psychology: Human Learning and Memory*, *3*(1), 52.

Majid, A., & Burenhult, N. (2014). Odors are expressible in language, as long as you speak the right language. *Cognition*, *130*(2), 266-270.

Maric, Y., & Jacquot, M. (2013). Contribution to understanding odour–colour associations. *Food Quality and Preference*, *27*(2), 191-195.

Mur, M., Bandettini, P. A., and Kriegeskorte, N. (2009). Revealing representational content with pattern-information fMRI—an introductory guide. Social Cognitive and Affective Neuroscience, 4(1):101-109.

Palmer, S. E., & Schloss, K. B. (2010). An ecological valence theory of human color preference. *Proceedings of the National Academy of Sciences*, *107*(19), 8877-8882.

Palmer, S. E., Schloss, K. B., Xu, Z., & Prado-León, L. R. (2013). Music–color associations are mediated by emotion. *Proceedings of the National Academy of Sciences*, *110*(22), 8836-8841.

Pangborn, R. M., Guinard, J. X., & Davis, R. G. (1988). Regional aroma preferences. *Food Quality and Preference*, *1*(1), 11-19.

Regier, T., & Kay, P. (2009). Language, thought, and color: Whorf was half right. *Trends in Cognitive Sciences*, *13*(10), 439-446.

Shankar, M. U., Levitan, C. A., & Spence, C. (2010). Grape expectations: The role of cognitive influences in color–flavor interactions. *Consciousness and Cognition*, *19*(1), 380-390.

Spector, F., & Maurer, D. (2012). Making sense of scents: the colour and texture of odours. *Seeing and Perceiving*, *25*(6), 655-677.

Spence, C. (2011). Crossmodal correspondences: A tutorial review. *Attention, Perception, & Psychophysics*, *73*(4), 971-995.

Stevenson, R. J. (2001). Associative learning and odor quality perception: how sniffing an odor mixture can alter the smell of its parts. *Learning and Motivation*, *32*(2), 154-177.

Stevenson, R. J., Boakes, R. A., & Prescott, J. (1998). Changes in odor sweetness resulting from implicit learning of a simultaneous odor-sweetness association: An example of learned synesthesia. *Learning and Motivation*,*29*(2), 113-132.

Stevenson, R. J., Rich, A., & Russell, A. (2012). The nature and origin of cross-modal associations to odours. *Perception*, *41*(5), 606.

Winawer, J., Witthoft, N., Frank, M. C., Wu, L., Wade, A. R., & Boroditsky, L. (2007). Russian blues reveal effects of language on color discrimination. *Proceedings of the National Academy of Sciences*, *104*(19), 7780-7785.

Wnuk, E., & Majid, A. (2014). Revisiting the limits of language: The odor lexicon of Maniq. *Cognition*, *131*(1), 125-138.

Yeshurun, Y., & Sobel, N. (2010). An odor is not worth a thousand words: from multidimensional odors to unidimensional odor objects. *Annual Review of Psychology, 61*, 219-241.

Zellner, D. A. (2013). Color–Odor Interactions: A Review and Model. *Chemosensory Perception*, *6*(4), 155-169.

Zellner, D. A., Bartoli, A. M., & Eckard, R. (1991). Influence of color on odor identification and liking ratings. *The American Journal of Psychology*, *104*(4), 547-561.