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Smelling Shapes: Crossmodal Correspondences Between Odors and Shapes

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Abstract

Crossmodal correspondences between odors and visual stimuli—particularly colors—are well-established in the literature, but there is a paucity of research involving visual shape correspondences. Crossmodal associations between 20 odors (a selection of those commonly found in wine) and visual shape stimuli ("kiki"/"bouba" forms—Köhler W. 1929. *Gestalt psychology*. New York: Liveright.) were investigated in a sample of 25 participants (mean age of 21 years). The odors were rated along a form scale anchored by 2 shapes, as well as several descriptive adjective scales. Two of the odors were found to be significantly associated with an angular shape (lemon and pepper) and two others with a rounded shape (raspberry and vanilla). Principal component analysis indicated that the hedonic value and intensity of odors are important in this crossmodal association, with more unpleasant and intense smells associated with more angular forms. These results are discussed in terms of their practical applications, such as in the use of bottle, logo, or label shape by marketers of perfume and wine to convey the prominent notes through congruent odor–shape pairing. In conclusion, these results support the existence of widespread crossmodal associations (or correspondences) between odors and visual shape stimuli.

Key words: crossmodal associations, crossmodal correspondences, odors, shapes

Introduction

The environments in which we live are multisensory; often even the simplest of everyday activities entail the interaction of multiple sources of sensory information. The task of eating a meal, for instance, involves a barrage of inputs from the different sensory modalities, some of which are combined in the perception of flavor. Crossmodal correspondences (or associations) may thus reflect a strategy by which the human brain (not to mention the brains of other species; see Ludwig et al. 2011) can quickly and effectively deal with complex sensory inputs; as Spence and Zampini (2006, p. 1009) put it, a "range of implicit perceptual and cognitive processes are continually engaged in blending and segregating information from diverse sources". Crossmodal correspondences, then, may help an organism to solve the crossmodal binding problem, that is, to know which of several stimuli that happen to be presented in different modalities at any given time are likely to belong together (see Ernst 2007; Spence 2011). Further, by using a preferential looking methodology, visual-auditory correspondences have been shown to be present as early as 3- to 4-months of age (Walker et al. 2010). The crossmodal correspondence between visual lightness and auditory pitch has recently been demonstrated in chimpanzees as well (Ludwig et al. 2011), thus confirming their widespread existence during development and across species. In terms of consumer research, certain expectations may be borne out of crossmodal associations. Consumers will rate food and drink products more highly if they meet their expectations than if they do not (Spence 2012; Yeomans et al. 2008). Therefore, studying crossmodal associations is a worthwhile endeavor, not only for its theoretical value but for its practical implications for fields such as advertising and food marketing. Perhaps it is no surprise, then, that there has been a growth in interest in studying crossmodal interactions in recent years—especially in relation to flavor perception.

For a small minority of individuals, crossmodal experiences manifest themselves in a more extreme form—namely, synesthesia. Synesthesia refers to the phenomenon whereby stimulation in one sensory modality automatically triggers a conscious perception, often in a second modality (Cytowic, 1993). Although some researchers have argued that crossmodal correspondences should be considered as a weak form of synesthesia (e.g., Martino and Marks 2001), there are a number of key differences between the condition and findings of crossmodal correspondences—the meaning of synesthesia may be distorted if the term is applied too readily or broadly (see Deroy and Spence [in preparation]; Spence 2011). Not least of these differences, the perception of, for example, a certain shape is "involuntary" in response to tastes or flavors in taste/flavor-shape synesthetes. This contrasts with the propensity for certain attributes to be linked crossmodally, but, crucially, not perceived concurrently nor involuntarily in neurologically normal individuals.

Research on the topic of crossmodal associations (or correspondences) arguably finds its roots in the classic research reported by Köhler (1929; see also Sapir 1929), where it was demonstrated that there was a nonarbitrary association between the auditory and visual domains under certain conditions. The speech sounds "baluba" and "takete" were to be attributed to 2 visual shapes (see Figure 1). It was found that these stimuli were very often paired by participants in a nonrandom (i.e., specific) manner. There was a strong preference for "baluba" to be associated with a curvy, rounded shape, and for "takete" to be paired with a sharp, angular one. The same result has now been demonstrated in a wide variety of cultures (Bremner et al. [in press]).

This phenomenon has been explained in terms of a matching of the sharp directional changes of the lines of the angular shape with the sharp phonemic inflections of the sound "takete" (or "kiki"), as well as the sharp inflection of the tongue on the palate (see Ramachandran and Hubbard 2001). This simple result turns out to be surprisingly robust, with replications obtaining the same general finding with an array of different word stimuli being used (e.g., Köhler 1947—"takete" and "maluma"; Ramachandran and Hubbard 2001—"kiki" and "bouba").

Crossmodal correspondences between speech sounds and visual shapes are thus well-documented in the literature, and as such, more attention has been directed toward research into perceptual interactions involving the other senses. Of particular interest in terms of the present study is research involving the sense of smell. Crossmodal associations and interactions between odors and auditory stimuli—specifically pitch—have been reported in a number of studies. Participants display a consensus in ordering certain smells by ascending pitch (Belkin et al. 1997; see also Crisinel and Spence 2012), and congruent auditory information can modulate the perceived pleasantness of an odor (see, e.g., Seo and Hummel 2011). Properties such as hedonic value and complexity have been found to be important factors

Figure 1 Typical angular and rounded shapes similar to those used in Köhler's (1929) original study.

in terms of the matching of odor and pitch (Crisinel and Spence 2012; cf., Schifferstein and Tanudjaja 2004).

Research into the links between odors and visual stimuli is arguably a more piecemeal domain. Different visual stimuli have been utilized in different studies. Predominantly though, color has been used; for instance, nonrandom linking across participants between odor and color hue has been widely established (e.g., Demattè et al. 2006; Gilbert et al. 1996), and the robustness of such correspondences has been demonstrated both explicitly (i.e., correspondences have been documented to remain stable after 2 years—Gilbert et al. 1996) and implicitly (Demattè et al. 2006). More intense smells are associated with darker colors (Kemp and Gilbert 1997). Using a different type of visual stimulus, Gottfried and Dolan (2003) reported that semantically congruent, as opposed to incongruent, pictorial images resulted in faster and more accurate olfactory detection. However, considerably less research has been conducted into the possible existence of crossmodal matches between odors and shapes.

Seo et al. (2010) recently conducted a study in which they utilized abstract symbols. The study demonstrated that certain symbols were consistently paired with specific odors across participants, and that subsequent odor-symbol congruency modulated odor pleasantness, as well as increased the amplitude of olfactory event-related potentials in the human brain. However, despite this scarcity of research on the topic, the shape of perfume bottles is considered as a key element in determining the success of a new perfume (e.g., Caldwell and Flammia 1991). The shape of the packaging and/or label of many food and nonfood fragrant products is also strongly associated with specific brands (see Spence and Piqueras-Fiszman forthcoming).

The present study was designed to investigate any associations that exist between odors commonly found in wines (using the same stimulus set as in Crisinel and Spence 2012) and visual shape stimuli, namely the angular and rounded shapes classically used in studies of word-shape association. The odors used represent a wide range of categories (e.g., flowers, fruits, or spices), including stimuli with a trigeminal component, such as pepper. The use of odors related to wine seems interesting considering the propensity for wine writers to describe wines with reference to shape. For instance, a wine may be described as sharp or well-rounded (e.g., see Lehrer 2009; Peynaud 1996). Such descriptors are used to describe the flavor of the wine as a whole, but given the important role played by retronasal olfaction in flavor perception (see, e.g., Shepherd 2006), one can hypothesize that similar crossmodal correspondences exist for wine-related odors smelled orthonasally (although note that here single components of wine odors were used). The present study goes beyond the seminal work of Seo et al. (2010) in that we used a different selection of olfactory stimuli together with a more controlled shape dimension (here, a scale from more angular in shape to more rounded in shape, see Figure 2). Our hypothesis was that crossmodal associations would be obtained between the wine odor stimuli and the angular and rounded shapes.

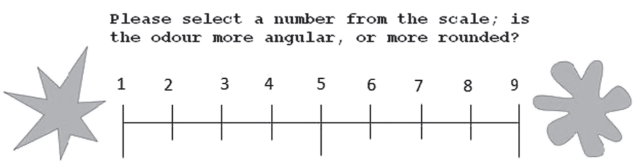

Figure 2 Scale used to rate the association of each odor with the angular or rounded shape.

Materials and Methods

Participants

Twenty-five individuals participated in the experiment (15 female and 10 male; mean = 21.2 years old, range = 20–30 years), from a population at the University of Oxford. None of the participants reported a cold or any other impairment of their sense of smell prior to taking part in the study.

The experiment complied with the standards set in the Declaration of Helsinki for Medical Research involving Human Subjects and was approved by the Central University Research Ethics Committee of Oxford University.

Stimuli

Twenty odors (out of 54) from the "Nez du Vin" set (see www.nezduvin.co.uk/nezduvin_54.htm)—a kit designed to train amateur wine tasters to recognize and describe the aromas found in wine—were used as olfactory stimuli (almond, apple, apricot, blackberry, caramel, cedar, dark chocolate, cut hay, green pepper, honey, lemon, liquorice, mushroom, musk, pepper, pineapple, raspberry, smoked, vanilla, and violet). These particular samples were used in order to cover a broad range of aromas, and further, to facilitate comparisons with findings from past research, which selected exactly the same odors (Crisinel and Spence 2012). The odors were contained in small transparent numbered glass bottles. Thus, without a covering, the color of the liquid inside was visible. The color of the liquids ranged from transparent to dark brown. In order to check any effect the color of the liquid might have on the various ratings, for a subset of the participants (N = 10), the bottles were covered with white stickers.

For the visual stimuli, angular and rounded shapes were used as the anchors on a 9-point scale (with the angular "kiki" shape on the left side and the rounded "bouba" shape on the right—see Figure 2). Fifteen adjective scales were also presented, with the descriptors: complex, intense, pleasant, familiar, floral, fruity, acrid, earthy, nutty, spicy, woody, bitter, salty, sour, and sweet. These were also rated on a 9-point scale (from "not at all" on the left side, to "extremely so" on the right) and text accompanied each scale asking participants to what extent the current odor was, for example, "complex."

Procedure

The experimenter obtained informed consent before participants took part in the study. The participants were seated in a darkened booth and were then handed the first bottle. The order of odors was randomized for each participant. They were instructed that they could sniff the odor as much as they wished. Each odor was to be rated on a series of dimensions, with the experiment programmed in E-Prime (Version 1.2). This included a dimension of shape, with a scale anchored on one end by an angular shape and on the other by a rounded shape. Following the shape dimension, 15 adjective scales were presented, one at a time, in a random order. After all of the ratings had been made for the first odor, that bottle was taken away by the experimenter and the next one was provided, until all 20 odors had been rated by the participant. The experiment typically lasted for approximately 40 min. The participants were told that they could withdraw from the study at any time should they so desire (though none did).

Results

In order to test for an unwanted effect of the visibility of the color of the odor liquid, two-way (20 × 2) mixed analyses of variance were conducted for all ratings, with the within-subjects variable of odor and the between-subjects variable of bottle covering. It was found that although there were significant main effects of odor on all ratings ($P < 0.001$), there were no significant main effects of the bottles being covered, except for the familiarity rating ($P = 0.008$), nor were there significant interactions between odors and the bottles being covered, suggesting that visual information from the transparent odor bottles did not affect the participants' ratings.

One-way t-tests were carried out in order to assess which of the individual odors were significantly different from the scale's midpoint (thus, the test value was set to 5). Bonferroni adjusted alpha levels of 0.0025 were used (0.05/20). The significantly angular aromas were lemon—$t(24) = -3.73$, $P = 0.001$, and pepper—$t(24) = -3.54$, $P = 0.002$. Odors that were judged to be significantly rounded were raspberry—$t(24) = 4.23$, $P < 0.001$, and vanilla—$t(24) = 3.94$, $P = 0.001$ (see Figure 3).

Factor analysis was conducted on the data. Principal component analysis (PCA) was used on the 15 adjective ratings as well as the rating of shape, using SPSS version 19. The Kaiser–Meyer–Oklin measure of sampling adequacy (Kaiser 1970, 1974) was 0.65 and Bartlett's test of sphericity (Bartlett 1954) was significant, so the data were of sufficient quality to proceed. From the component matrix 3 components were extracted, with eigenvalues of at least 1.0. These accounted for 83.5% of the total variance; 58.6%, 18.5%, and 6.4% for the 3 components, respectively. Based on inspection of the scree plot, 2 components were retained, and Varimax rotation was performed. Consequently, the first component now accounted for 54.0% of the variance, and the second component for 23.1%. The first factor had strong (>0.05) positive loadings of acrid, bitter, complex,

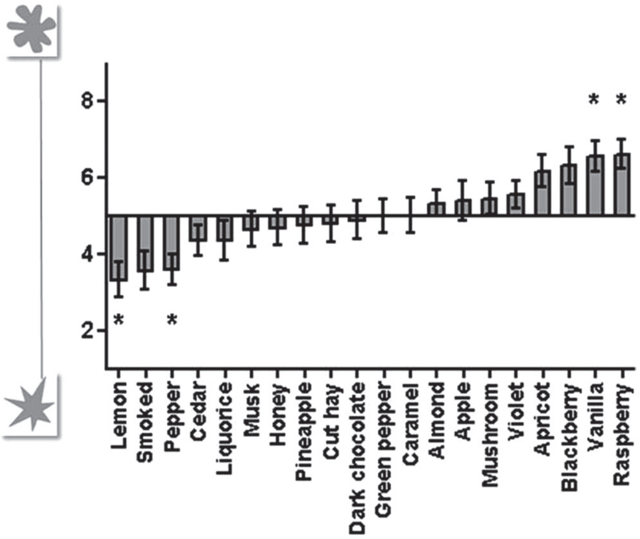

Figure 3 Mean shape score of each of the 20 odor samples, ordered according to their value; error bars indicate the standard errors, and asterisks denote the odors that were significantly different from the scale's midpoint of 5.

earthy, nutty, salty, spicy, and woody, while it had strong negative loadings of floral, fruity, pleasant, and sweet (see Figure 4A). This could be argued to characterize the hedonic value, but also seems to represent complexity. The second factor had strong positive loadings of acrid, bitter, familiar, intense, and sour. This, then, seems to be linked to intensity, in particular the intensity of sourness. The lemon odor had the highest score on this component. The shape ratings had negative loadings on both the first (−0.44) and second (−0.80) component. Scores for each odor are shown in Figure 4B.

Discussion

The results of the experiment reported here further our understanding of the crossmodal correspondences that exist between odors and visual stimuli; the hypothesis that cross-modal associations between visual shape and odor would be obtained was supported. These associations are shared, but further research will be needed to establish their stability over time in individuals (cf., Gilbert et al. 1996). This result builds on the existing findings of links between odor and color (Demattè et al. 2006; Gilbert et al. 1996; Kemp and Gilbert 1997; Schifferstein and Tanudjaja 2004) and helps to confirm and extend—in a more controlled, dimensional way—an underrepresented area in the literature: namely crossmodal associations between odor and abstract symbols/shapes (Seo et al. 2010). The results indicated that the lemon and pepper odors were significantly associated with the angular shape, whereas the raspberry and vanilla odors were significantly associated with the rounded one instead. The other odors tested might be associated with intermediate shapes (partly rounded, partly angular). However, the scale used does not allow one to differentiate between an absence of any association with shapes and an association with an intermediate shape for ratings around the midpoint of the scale. Further studies could disambiguate these results by using intermediate shapes along the scales, and/or having a separate scale to rate the strength of the matching.

Interestingly, the results of the present study are similar to those of studies that have used the sense of taste, rather than the sense of smell, in their crossmodal research. For instance, sweet tastes have been found to be associated with roundedness, and bitterness is associated with angularity. Ngo et al. (2011), for example, found that sweet milk chocolate was rated as more rounded, and bitter dark chocolate was associated with sharper shapes. Elsewhere, participants in a study by Deroy and Valentin (2011) linked sweet beers (as opposed to acidic ones) with more rounded shapes. Considering that odors easily acquire taste properties when they have been experienced together (Stevenson et al. 1995), the finding that vanilla and raspberry are rated as significantly rounded seems to accord well with this propensity for sweetness to be linked with roundedness. Likewise, it is interesting to note that lemon, a typically sour/bitter odor (note that people sometimes confuse sour and bitter—see Hettinger et al. 1999) was rated as significantly angular. One can also wonder whether the trigeminal system plays a role in the crossmodal associations with shapes, as the pepper odor, which has a strong trigeminal component, was associated with the angular shape.

The results of the PCA suggest that perceived intensity and sourness are important factors in crossmodal correspondences: More intense and sour odors tend to be associated with a more angular shape, whereas more subtle ones are associated with the rounded shape. Hedonic value was also found to be a factor in the crossmodal correspondence. That is, the strong negative loading of shape onto the hedonic component suggests that unpleasant (i.e., intensely bitter, sour, acrid) odors are associated with a more sharp, angular form. The finding that hedonic value is involved accords well with previous results showing that pleasantness is the most salient or dominant underlying dimension in odorants (see, e.g., Zarzo 2008), although the crossmodal correspondences observed here are not entirely explained by the hedonic value of the stimuli. Further, other studies of crossmodal associations have demonstrated that hedonic value is involved in correspondences, for example, between odor and musical pitch (Crisinel and Spence 2012). Moreover, the results of the present study are consistent with previous evidence that angularity is unpleasant (see Bar and Neta 2006). However, other factors such as odor intensity and complexity, as well as the presence of a trigeminal component, should certainly be explored to provide a more comprehensive understanding of the correspondences.

An idea for future work stemming from these findings is the addition of an implicit association test to assess the robustness of the study's cross-modal associations. Prior work has

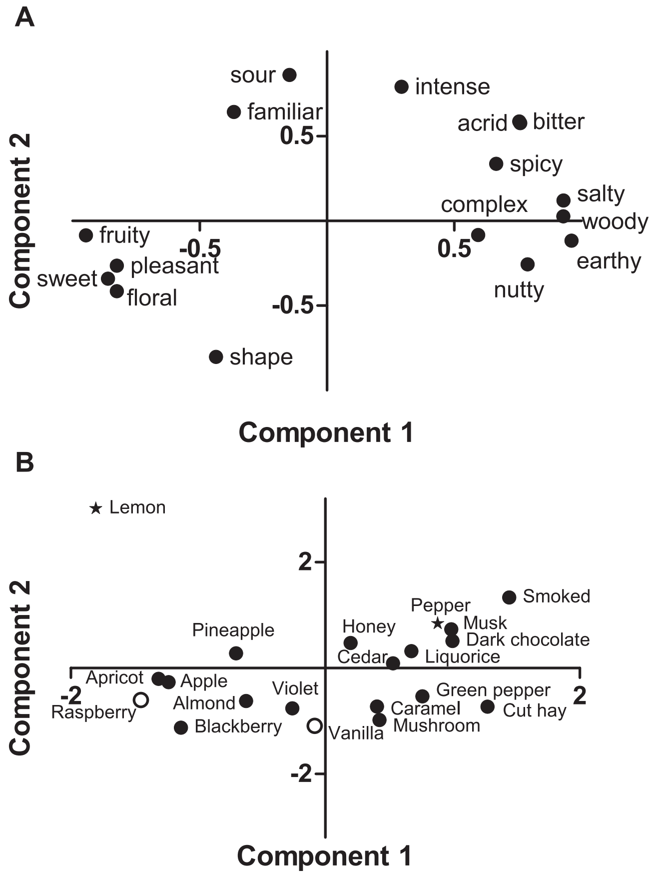

Figure 4 Loading plot from the PCA conducted on the various ratings of the odors (**A**). Note that a higher rating on the shape scale corresponds to a stronger association with the rounded shape. Score plot of the odors (**B**). Odors that were significantly associated with the angular shape are represented by a star, whereas those that were associated with the rounded shape are represented by an open circle.

already utilized this methodology; for example, Demattè et al. (2006) reported that participants responded faster, and more accurately, to odor-color pairings that were strongly associated with each other as opposed to when there was a weak association or else no association. Here, the most angular odors (such as lemon and pepper) and the most rounded ones (such as raspberry and vanilla) could be paired with the shapes to test for facilitatory effects and to test for the robustness of the associations. Other research has found that congruent pictorial shapes (e.g., the shape of a strawberry when smelling that aroma), as well as color information, can aid olfactory discrimination (Demattè et al. 2009). Colors and pictorial cues seem to lead to the access of an object's representation at different levels of information processing, with color activating a perceptual level, whereas pictorial involves a semantic level (see Naor-Raz et al. 2003). With the present study, however, it could be predicted that shapes would influence the perceptual features of odors as, unlike the shapes utilized in Demattè et al. (2009), those used here were abstract, and not pictorial (i.e., they were not explicitly linked to, nor did they signify, a certain odor). Indeed, previous research on correspondences between odors and abstract symbols has demonstrated effects of shape congruency on odor intensity and pleasantness ratings (Seo et al. 2011).

The practical implications of the results expand into the marketing of products such as perfumes, beverages, and foods (see Spence and Piqueras-Fiszman forthcoming). It is important to note that synesthetic, crossmodal language is often used in advertising and marketing. It has been shown that adverts using this kind of phrasing are rated as being more pleasant and novel than those using literal language, especially if they can stimulate a sense that cannot be stimulated directly by the object in question; for instance, using language relating to sounds when advertising perfume (see Nelson and Hitchon 1999). One reason, therefore, why certain fragrances are successful could be due to the appropriate use of congruent shape-smell pairings—both perhaps in terms of geometric shape images on the packaging and the form of the bottle itself. Indeed, there are many options and opportunities for perfume marketers in the area of innovative bottle design. Two successful perfumes—DKNY's "Golden Apple" and "Nina" by Nina Ricci—utilize rounded bottles in the form of an apple. There is a semantic congruency here already, as these perfumes contain notes of apple, but further, some degree of a link to hedonic value might be hypothesized given the present results.

In addition, given that the present study used wine odors, bottle, logo, and label shapes could be manipulated in the marketing of wines in order to capture the prominent note. For instance, for a fruity wine with strong notes of raspberry, then the results reported here indicate that more rounded shapes would be better than in the case of a wine that had prominent lemon or pepper notes. One should note, though, that a wine's aroma typically consists of a complex combination of olfactory notes. Further research will therefore be needed to determine, for example, what shape is considered congruent for a wine that combines notes associated with angularity and roundedness. The use of shape in wine marketing could aim to be congruent with, for instance, whether it is an overall "sharp" or "well-rounded" wine (see Lehrer 2009; Peynaud 1996). In doing so, this could lead to more positive perceptions of the product from consumers, with its key sensory features underscored through marketers' attention to crossmodal correspondences (e.g., see Gal et al. 2007).

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