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The shapes associated with the concept of ‘sweet and sour’ foods

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FOOD QUALITY AND PREFERENCE

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ABSTRACT

Research on taste-shape correspondences has focused on one-to-one taste/shape matching tasks. However, foods and drinks tend to involve multiple shapes (or shape attributes) and tastes that co-occur at different moments of our eating experiences. In the present research, we assessed whether food concepts involving more than one taste (e.g., “sweet and sour”) would be associated with pairs of round and/or angular shapes. The participants matched shape pairs comprising angular and round shapes with “sweet and sour” food concepts more often than with other taste and taste combination concepts, in a manner that is broadly consistent with studies involving one-to-one taste/shape matches. These results were observed both when the participants were presented with the shape pairs alone (Experiment 1) or along with a product’s packaging (Experiment 2). We conclude by presenting possible explanations for the results obtained, as well as directions for future research.

KEYWORDS: Sweet and sour, taste, shape, crossmodal correspondences, packaging.

Introduction

People generally see foods and drinks before consuming them. In fact, in many cases, people are exposed to a number of visual elements such as labels, packages, and menus, and their many corresponding visual features (e.g., colours, shapes, visual textures), before eating. Crucially, research has shown that visual elements associated with foods and drinks can influence people’s taste and flavour expectations and, under certain circumstances, also their experiences (Delwiche, 2012; Imram, 1999; Spence et al., 2016; Van Rompay et al., 2017; Zellner et al., 2018). That said, it is critical to understand how and why this happens, given that even subtle visual cues (e.g., luminance, contour) might have significant implications for consumers’ food and drink behaviours (e.g., Spence & Velasco, in press).

Multiple factors seem to guide how visual cues influence taste and flavour expectations. For example, consumers might expect that the flavour of a crisps’ product is that of “tomato”, when the packaging is red, because both colour and flavour belong to the same object identity or meaning (tomato), in a given product category (crisps, Velasco et al., 2015). These kinds of associations might be based on associative learning and therefore variations might occur across different groups of consumers (Shankar, Levitan, & Spence, 2010; Velasco et al., 2014). In recent years though, it has also been demonstrated that expectations might also derive from crossmodal correspondences (e.g., Mirabito et al., 2017; Fenko, Lotterman, & Galetzka, 2016); that is, associations that people make between features across the senses (Spence, 2011). For example, people associate sweetness with red and sourness with green/yellow hues (Koch & Koch, 2008; O’Mahony, 1983; Spence et al., 2015). Moreover, it has been documented that people associate sweet and sour tastes with higher-pitched notes and umami and bitter tastes with lower-pitched notes (Crisinel & Spence, 2012; Watson & Gunther, 2017). Perhaps common to the different kinds of crossmodal correspondences is the idea that they may not be easily pin pointed to a single common object identity or meaning (Parise, 2016; Spence et al., 2015).

Multiple correspondences between visual features and tastes have been reported in the literature (e.g., Becker et al., 2011; Spence & Ngo, 2012; Turoman et al., in press). Relevant to the present study, it has been demonstrated that people match tastes with shape curvature, such that round shapes are more strongly associated with sweet taste and more angular shapes with tastes such as bitter and sour (see Blazhenkova & Kumar, in press; Deroy & Valentin, 2011; Ngo, Misra, & Spence, 2011; Velasco et al., 2015). This research has also provided evidence for the idea that rounder shapes, as used in, for example, food-related packaging or typefaces, tend to enhance sweetness expectations (Velasco et al., 2014) and, under certain circumstances, even influence its perception (van Liang et al., 2013; Rompay et al., 2017; Velasco, Hyndman, & Spence, 2018; though see Machiels, 2018).

Most studies on taste/shape matches, independently of whether they include abstract or, say, packaging shapes, have been based on experiments involving one-to-one taste/shape matches (see Velasco et al., 2016, for a review). In these experiments, the participants are typically presented with a shape and then asked to rate it on taste scales and/or given a taste and then asked to match it to one of a series of shapes. However, when we interact with foods and drinks, we are generally exposed to a range of visual and taste attributes. Just think of a regular product and its corresponding packaging. The packaging involves colours, multiple shape attributes, and even sonic features, and the food or drink product usually involves of more than one taste quality (see Spence, 2016, for a review on multisensory packaging).

Nevertheless, to the best of our knowledge, there are no studies as yet studying how, say, food concepts such as “sweet and sour” (e.g. Uncle Ben’s sweet and sour sauce) or “bitter and sweet” (e.g., a lemon cake), which are used to describe many foods (and involve more than one taste), might relate to specific shape attribute combinations (e.g., curvature, symmetry, complexity, etc., see Palmer, Schloss, & Sammartino, 2013, for a review on visual aesthetics and preference). This is important because several features tend to co-occur when it comes to eating and drinking and therefore, expectations may not necessarily be driven by single but rather several of them. Combinations of shape attributes in turn, may determine the overall “shape feel”, that is, the sensation evoked by the combined shape properties associated with a food or drink object. Research on the association between colour combinations and tastes may be informative here. Woods and Spence (2016) and Woods, Marmolejo-Ramos, Velasco, & Spence (2016) provided evidence for the idea that pairs of colours arranged as foreground/background, may in some cases better convey a specific taste relative to individual colours (see also Jacquot, Noel, Velasco, & Spence, 2016 on the associations between odours and multi-colour patches). Nevertheless, this research focuses on single tastes only.

In order to evaluate the association between multiple taste and shape attributes, in the present study we take a closer look at the concept of “sweet and sour” foods and explored how it relates to different pairs of shapes. In particular, across two experiments, we explore whether specific combinations of round and angular shapes would better convey the concept of “sweet and sour” foods. In Experiment 1, we presented the participants with different combinations/pairs of circles and triangles and asked them to pick the taste, among single (e.g., sweet) and composed (“sweet and sour”) food tastes, that best matched the shapes. In Experiment 2, we presented the participants with a subset of the shape combinations used in Experiment 1. In this experiment though, the shapes were incorporated in different packages of various food products. The participants were asked to select the taste that best matched the product.

Experiment 1

Methods

Participants. One hundred participants (72 females and 28 males) between the ages 18 and 49 years (*M* = 31.95 years, *SD* = 8.79) were recruited from Prolific Academic to take part in the Experiment 1 in exchange for £0.50. The experiment was designed and performed on Qualtrics software and lasted for approximately 5 minutes. All participants were fluent in English. Both Experiments 1 and 2 followed the Declaration of Helsinki.

Apparatus and materials. The stimuli included four images, each consisting of a combination of two shapes, a circle and/or a triangle, displayed side by side with equal dimensions and resolution. The shape combinations were two circles, one circle and one triangle, one triangle and one circle, and two triangles (see Figure 1, for the full stimuli set; stimuli of Experiments 1 and 2 can be accessed here: osf.io/f8b4p). The shapes presented were all white with a black outline. Qualtrics (bino.qualitrics.com) was the survey system used to collect data.

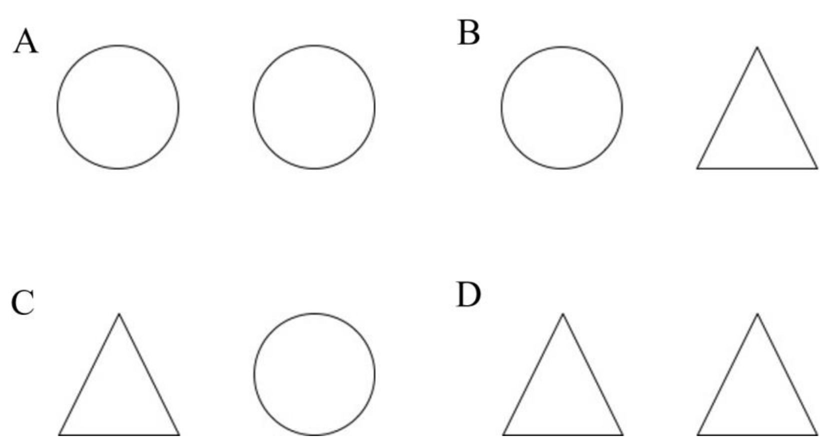

Figure 1. Images of shape combinations composed of two circles (1), one circle and one triangle (2), one triangle and one circle (3), and two triangles (4) used in Experiment 1.

Design and procedure. The experiment followed a 4 × 5 within participant design with factors shape-pair factors (circle-circle, circle-triangle, triangle-circle, and triangle-triangle) and taste (sweet, sour, “sweet and sour”, “sweet and salty”, and “sour and bitter”). At the beginning of the experiment, the participants were presented with the general aims of the study (“we are interested in understanding how people associate food tastes and shapes”) and were asked to sign a standard consent form. Once they agreed to take part in the study, they were asked to report their age and gender. After that, they moved on to the actual experiment. The four base stimuli were each presented four times for a total of 16 trials (see Figure 2, for a sample trial). Note that we presented the combinations circle-triangle and triangle-circle with the same shape pair but in different positions to control for any position effects. Four trials were presented in random order throughout four blocks of trials. The participants were instructed to choose one food taste they associated with the pair of shapes on the screen. The available taste options were sweet, sour, sweet and sour, sweet and salty, and sour and bitter. The position of the five taste options given in each trial was randomized. These taste options were selected based on the literature involving one-to-one taste/shape matches, which suggests that sweet is more strongly associated with round shapes and sour, bitter, and salty with angular shapes instead (see Velasco et al., 2016, for a review). Sweet and sour were included as single tastes as the associations between these tastes and shape curvature is strong (Velasco et al., 2015), thus, serving as a reference point. “Sweet and sour”, “sweet and salty”, and “sour and bitter” were included as tastes combinations. The decision to include them was to assess whether “sweet and sour” (which involves a round and an angular taste) would be matched to shapes differently from “sweet and salty” (which also involves a round and an angular taste), and whether these would be matched to shapes differently from “sour and bitter” (which involves two angular tastes). This, in other words, would allow us to assess whether the results were specific to particular combinations of tastes and shapes or consistent with one-to-one taste/shape matches. It is also worth mentioning that, the idea of presenting the shapes first, followed by the taste options, was aimed at emulating the way in which people usually first see foods before eating them.

There was no time limit to respond to each question. At the end of the experiment, the participants were presented with two control questions in random order. The first question instructed them to indicate how much they liked each of the five food tastes on a scale of 0 to 100. The second question instructed participants to indicate how familiar they were with each of the five food tastes on a scale of 0 to 100. The liking and familiarity ratings were included based on the idea that both of these variables may influence taste/shape matches (Velasco et al., 2016). These questions could also provide hints as to whether specific matches would be based on common liking and/or familiarity. Once again, the order of these tastes was presented in random order.

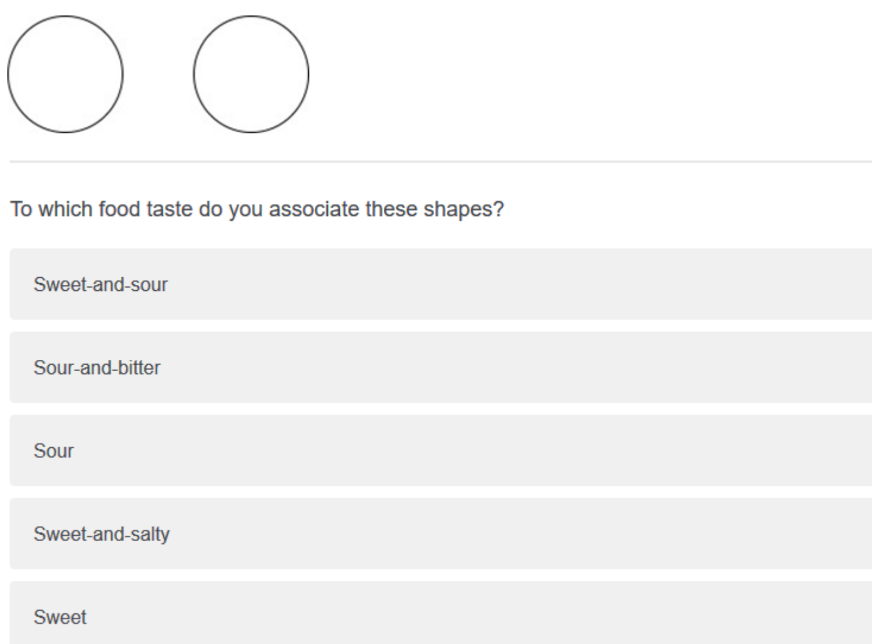

Figure 2. Sample trial in Experiment 1.

Analyses. The count data were analysed via a generalised linear model with the Poisson error distribution. The full model included the variables shape (S: circle-circle, circle-triangle, triangle-circle, and triangle-triangle), taste (T: sour, “sour and bitter”, sweet, “sweet and salty”, and “sweet and sour”), and gender (G: males and females), i.e. $freq = S * T * G$; where ‘*’ stands for main effects and interactions (interactions are represented by ‘:’). Likelihood ratio chi-squares (χ^2_{LR}) were estimated for each predictor via a type-II analysis-of-variance. In line with a multiverse analyses approach (Steegen et al., 2016), supplementary analyses were performed via multiple correspondence analyses (see Appendix). The key results of the model are shown via mosaic plots (Hartigan & Kleiner, 1984) and the tastes’ liking and familiarity ratings are represented via beanplots (Kampstra, 2008). Post-hoc comparisons of multiple dependent groups were performed via bootstrapped 25% trimmed means (see p. 429 in Wilcox, 2017; see also Field & Wilcox, 2017) with α=.05 (the mean differences, $\hat{\psi}$, and 95% CIs around them are reported).

Results and discussion

The likelihood ratio chi-squared statistics revealed a statistically significant association between taste (T) and gender (G) (T: χ^2_{LR}=207.12, *df*=4, *p*<.0001 and G: χ^2_{LR}= 320.62, *df*=1, *p*<.0001), an interaction between taste and shape (T:S: χ^2_{LR}=1207.06, *df*=12, *p*<.0001) and an interaction between shapes, taste, and gender (S:T:G: χ^2_{LR}=23.67, *df*=12, *p*=.02). Figure 3 (Experiment 1) represents visually the key results and Figure 4 (Experiment 1) displays the distributions of the ratings.

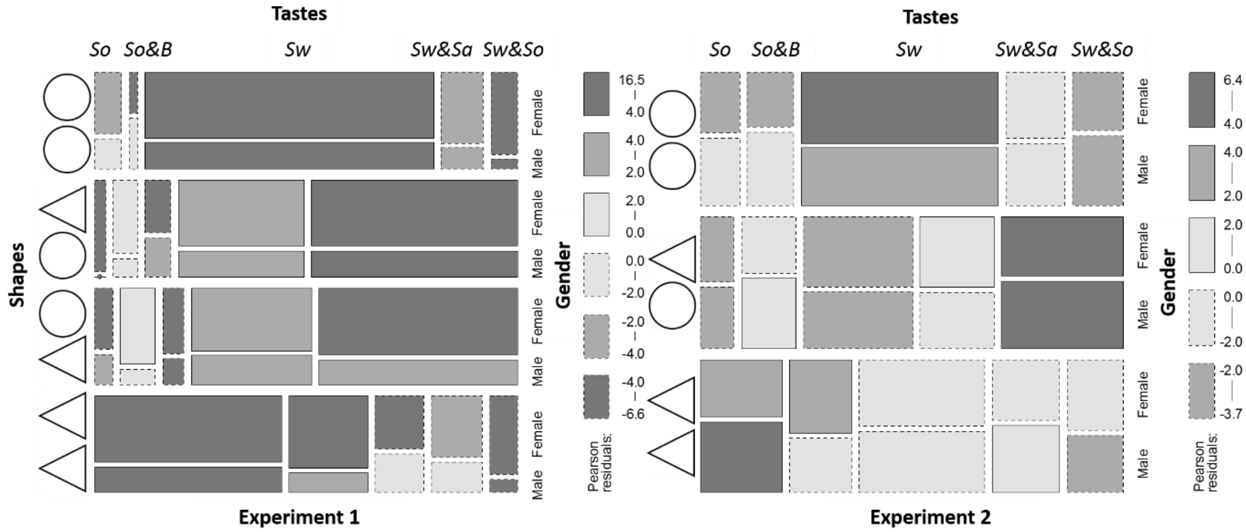

Figure 3. Mosaic plots representing the results of Experiments 1 and 2, where So=sour, So&B= sour and bitter, Sw=sweet, Sw&Sa = sweet and salty, and Sw&So = sweet and sour. Mosaic plots represents the proportions of responses visually, in this case, as a function of shape combinations presented and taste(s) selected. The area of the tiles is proportional to the number of observations within that category. No association between variables is shown when the tiles across categories all have the same areas. A proxy of an association occurs otherwise (see Hartigan & Kleiner, 1984, for details).

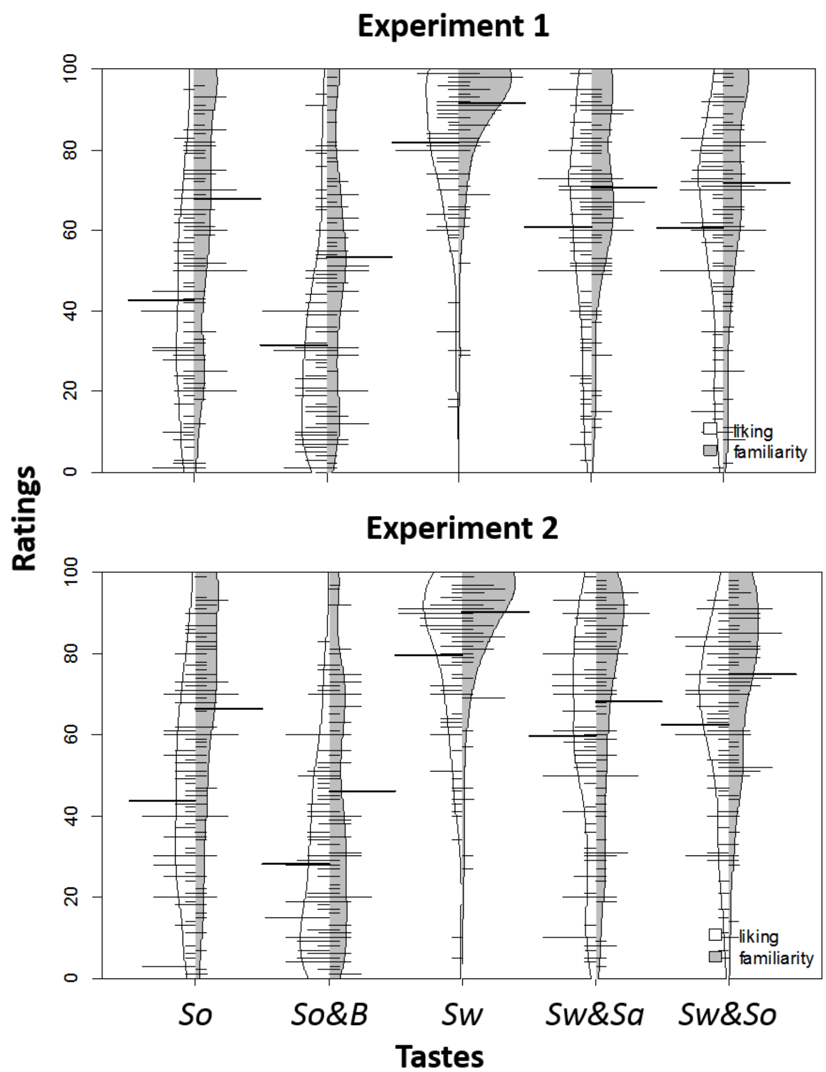

Figure 4. Beanplots representing the distribution of the tastes' familiarity and liking ratings in Experiments 1 and 2. So=sour, So&B= sour and bitter, Sw=sweet, Sw&Sa = sweet and salty, and Sw&So = sweet and sour.

Relevant to the aims of the present study, the mosaic plot in Figure 3 (Experiment 1) indicates that people associated circle-circle more strongly with sweet than the other tastes, circle-triangle and triangle-circle more strongly with "sweet and sour" than the other tastes, and triangle-triangle more strongly with sour than the other tastes (see also Appendix). The three-way interaction seems to suggest a difference between males and females in how often they associated triangle-circle with “sweet and sour”, with females doing it more often (though further analyses presented in the Appendix suggest that gender does not seem to be an important contributor to the association structure between shape and taste).

Furthermore, according to the liking and familiarity ratings of the different food tastes (Figure 4, Experiment 1), the participants preferred and considered more familiar sweet, relative to the other tastes, followed by “sweet and salty” and “sweet and sour”, and finally sour and “sour and bitter”. Post-hoc tests revealed that the following pairwise comparisons were not significant: Liking ratings: “sweet and sour” vs “sweet and salty” ($\hat{\psi}$= .78 [-10.57, 12.13]). Familiarity ratings: “sweet and sour” vs sour ($\hat{\psi}$= 4.72 [-4.48, 13.92]), “sweet and sour” vs “sweet and salty” ($\hat{\psi}$= 3.28 [-6.98, 13.54]), and sour vs “sweet and salty” ($\hat{\psi}$= -1.44 [-11.80, 8.92])

Overall, the results of Experiment 1 provide evidence for the idea that the shape combinations circle-triangle and triangle-circle are a better match for the concept of “sweet and sour” than other tastes. Whilst “sour and bitter” and “sweet and salty” were found by some participants to be also good matches for those shape combinations, this did not happen as often as for “sweet and sour”. In Experiment 2, we moved on to assess the association between different taste concepts and shape combinations in the context of product packaging.

Experiment 2

Methods

Participants. One hundred participants (51 females and 49 males) between the ages 18 and 48 years (*M* = 31.64 years, *SD* = 7.23) were recruited from Prolific Academic to take part in the Experiment 2 in exchange for £0.50. The experiment was designed and performed on

Qualtrics software and lasted for approximately 5 minutes. All participants were fluent in English.

Apparatus and materials. The stimuli consisted of 12 images. These included four generic packages corresponding to candy, jam, salad, and sauce products (P: candy, jam, salad, and sauce), each of them presented along with the three shape variants (two triangles, two circles, or one circle and one triangle, see Figure 5 for examples of the stimuli). Given that circle-triangle and triangle-circle were similarly associated with “sweet and sour” in Experiment 1, we decided to only include the shape combinations circle-circle, triangle-triangle, and circle-triangle in Experiment 2. Moreover, the specific products were selected based on the idea that they could comprise the tastes evaluated in Experiment 1. All images presented were in black and white and with the same dimensions and resolution. Qualtrics (bino.qualitrics.com) was the survey system used to collect data.

Figure 5. Examples of images consisting of a candy package with two circles (1), candy package with a circle and a triangle (2), jam package with two triangles (3),

sauce package with one circle and one triangle (4), salad package with two triangles (5), and a salad package with one circle and one triangle (6), used in Experiment 2.

Design and procedure. The experiment followed a 3 × 5 within participant design with factors shape (two circles, two triangles, and one circle and one triangle) and taste (sweet, sour, "sweet and sour", "sweet and salty", and "sour and bitter"). Experiment 2 followed a similar procedure to that of Experiment 1. In this case though, the 12 base stimuli were each presented twice (for a total of 24 trials) in order to obtain a more consistent estimate of the participants' responses. The 12 base stimuli were presented in random order across two consecutive blocks of trials. In each trial, the participants were also instructed to choose the food taste they associated with the product on the screen. In Experiment 2, the participants were also presented with control questions. In particular, three control questions were presented in random order. The first question instructed the participants to indicate how much they liked or disliked each other the five food tastes on a scale of 0 to 100. The second question instructed participants to indicate how familiar they were with each other the five food tastes on a scale of 0 to 100. The different taste words were presented in random order. The last question instructed participants to indicate how much they liked or disliked each of the three shape combinations on a scale of 0 to 100. The shape combinations were presented in random order.

Analyses. The data were analysed as in Experiment 1 though here the variable product (P: candy, jam, salad, and sauce) and that only three shape combinations used were added to the model (supplementary analyses were also performed via multiple correspondence analyses, see Appendix). As in Experiment 1, the key results of the model are shown via mosaic plots and the tastes' liking and familiarity ratings and the shapes' liking ratings are represented via beanplots.

Results and discussion

The likelihood ratio chi-squared statistics revealed a statistically significant effect of taste (T: χ^2_{LR}= 394.89, *df*=4, *p*<.0001), an association between taste and shape (T:S: χ^2_{LR}= 209.92, *df*=8, *p*<.0001), taste and product (T:P: χ^2_{LR}= 318.93, *df*=12, *p*<.0001), and an interaction between taste, gender and product (T:G:P: χ^2_{LR}= 38.13, *df*=12, *p*= 0.00014). Figure 3 (Experiment 2) presents the key results of the model and Figure 4 (Experiment 2) displays the distributions of the different ratings. In addition, Figure 6 presents the liking ratings associated with each of the shapes used in Experiment 2.

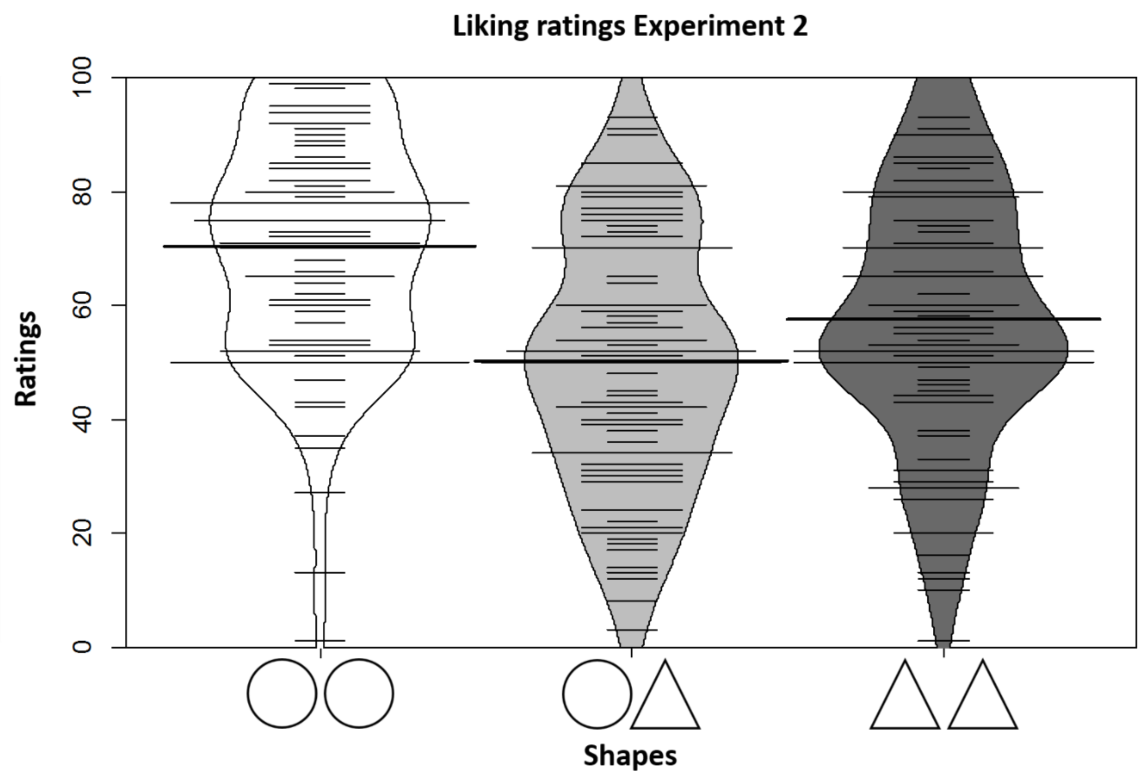

Figure 6. Beanplots representing the distribution of the shapes' liking ratings in Experiment 2. ○○ = median: 71.5 ~95% CI=[66.36, 76.63]; ○△= median: 50 ~95% CI=[44.31, 55.68]; △△= median: 54.5 ~95% CI=[50.07, 58.92].

The mosaic plot in Figure 3 (Experiment 2) shows that, as in Experiment 1, sweet was more strongly associated with circle-circle, “sweet and sour” with circle-triangle, and sour with triangle-triangle, than the other tastes (see also Appendix). The three-way interaction might suggest that females selected circle-circle more frequently for sweet than males, and males more frequently triangle-triangle for sour (though again see the corresponding analysis in the Appendix, which suggests that gender does not seem to be an important contributor to the association structure between shape and taste).

The liking and familiarity ratings of the food tastes in Experiment 2 were similar to those reported in Experiment 1 (see Figure 4, Experiment 2). The post-hoc tests revealed that the following pairwise comparisons were not statistically significant: Liking ratings: “sweet and sour” vs “sweet and salty” ($\hat{\psi}$= 2.56 [-6.64, 11.76]), and familiarity ratings: “sweet and sour” vs sour ($\hat{\psi}$= 7.60 [-1.64, 16.84]), “sweet and sour” vs “sweet and salty” ($\hat{\psi}$= 4.14 [-5.84, 14.12]), and sour vs “sweet and salty” ($\hat{\psi}$= -3.46 [-14.99, 8.07]). As for the shape ratings, it appears that the participants liked circle-circle more than the other shapes, followed by triangle-triangle, and circle-triangle, with more variability found in the latter (see Figure 6). Post-hoc pairwise comparisons indicated that the only difference that was not statistically significant was that between circle-triangle and triangle-triangle ($\hat{\psi}$= -7.58 [-15.18, .02]).

Motivated by previous research (Velasco et al., 2016), we performed additional analyses in order to assess whether similarity in the individual shape and taste liking ratings led to favouring matching those shapes and tastes over others. In other words, we wanted to assess whether similar liking ratings, meant that the corresponding shapes and tastes would be preferably matched over others. Based on the initial analysis performed for Experiments 1 and 2, we considered the following scenarios: circle-circle and sweet [scenario 1], triangle-triangle and sour [scenario 2], and circle-triangle and “sweet and sour” [scenario 3] liking ratings. For each scenario, the proportions of all the shape and taste pairings were estimated when the absolute difference between the liking ratings of the shape and taste of interest ranged between 0 and 34 (see Table 1). This range was decided upon dividing the range of liking ratings in three intervals of liking similarity in R language: cut(seq(1:100),3), where the 0 to 34 interval meant to capture cases of high similarity in the liking ratings. The cases of interest were those that overlapped with the shape and taste under scrutiny.

The results for scenario 1 (n=1800 or 75% of the trials, range liking rating = 5-100) showed that circle-circle was more likely to be paired with sweet than with any other taste and that the sweet was more frequently paired with circle-circle than with any other shape. In scenario 2 (n=1632 or 68% of the trials, range liking rating = 1-90) it was found that triangle-triangle was more frequently paired with sweet than with any other taste, being the triangle-triangle/sour the second most frequent pairing (only a difference of .02 between the two). The sour taste was more frequently paired with triangle-triangle than with any other shape. In scenario 3 (n=1848 or 77% of the trials, range liking rating = 5-100), circle-triangle and “sweet and sour” were more likely to be paired than circle-triangle and any other taste. By the same token, “sweet and sour” was more likely to be paired with circle-triangle than with any other shape.

Table 1. Proportions of shape and taste parings when the difference of liking between the absolute value of the liking ratings difference between sweet and circle-circle (scenario 1), sour and triangle-triangle (scenario 2), and “sweet and sour” and circle-circle (scenario 3), were between 0 and 34 (high liking similarity), in Experiment 2.

Taste	Sweet/Circle-circle (n = 1800)			Sour/ Triangle-triangle (n = 1632)			“Sweet and sour”/Circle-triangle (n = 1848)		
	Circle-circle	Circle-triangle	Triangle-triangle	Circle-circle	Circle-triangle	Triangle-triangle	Circle-circle	Circle-triangle	Triangle-triangle
Sour	0.03	0.03	0.08	0.04	0.03	0.08	0.03	0.03	0.07
Sour-bitter	0.04	0.04	0.06	0.04	0.05	0.05	0.04	0.04	0.05
Sweet	0.17	0.09	0.10	0.17	0.09	0.10	0.17	0.09	0.11
Sweet-salty	0.05	0.06	0.06	0.04	0.06	0.06	0.05	0.06	0.06
Sweet-sour	0.04	0.11	0.04	0.04	0.11	0.04	0.05	0.11	0.05

Overall, the results of Experiment 2 further support the findings of Experiment 1. It appears that a shape combination that includes a circle and a triangle is a better representation of “sweet and sour” than other shape combinations. In addition, there is a key point to highlight from the additional analyses. Given that the number of trials analysed summed 2400 per each scenario (12 stimuli x 2 repetitions x 100 participants), it is possible to suggest that most of the shape and taste liking ratings in each scenario were highly similar. That is, 75%, 68%, and 77%, of the cases (absolute value of shape liking – taste liking) in scenarios 1, 2, and 3, respectively, resulted in values between 0 and 34. This, together with the other results reported, indicate that the individual taste and shape liking ratings of the most frequent taste/shape matches share some level of similarity.

General discussion

Across two experiments, we assessed whether and what specific combinations of round and angular shapes would better convey the concept of “sweet and sour” foods. The results revealed that participants associated more strongly round/angular combinations, as represented by a circle and a triangle with “sweet and sour”, than other tastes. In addition, we found that shape pairs involving two round shapes (circles) or two angular shapes (triangles), are more frequently matched to sweet and sour tastes, respectively, relative to the other tastes. Importantly, these effects seem to be consistent both when the shapes are presented alone or as part of packages of different food products.

How to explain the idea that placing a round and angular shape side by side may better represent the concept of a “sweet and sour” food? Here, we would like to suggest possible explanations. On the first hand, given that both “sweet and sour” and “circle triangle” are stimuli composed by two tastes and two shapes, respectively, one alternative is that participants process them in a serial manner, one by one, and guide their associations based on the individual components of each stimulus (cf. Ashby, Prinzmetal, Ivry, & Maddox, 1996; Townsend, 1990). In this sense, the matching would be no different from those where participants are asked to match a single taste to a single shape. Based on previous research, as well as the results of Experiment 2, this would potentially indicate that the participants may match the different tastes and shapes as a function of their common affective properties and/or underlying meaning of the individual stimulus component (Velasco et al., 2016). One limitation of the current experiments worth mentioning here is the fact that we did not include single shapes, and therefore, it is not possible to assess whether shape combinations are better matches for tastes than single shapes.

An alternative interpretation, instead of the aforesaid one-taste-to-one-shape explanation, is that the shape and taste combinations are not processed as a function of their individual components but take on a new meaning, based on a sort of perceptual grouping (e.g., Wagemans et al., 2012), and such meaning is what drives the matching. Importantly, though, it has been suggested that combinations of attributes (i.e., colours) might be able to better convey the complexity of both tastes and flavours of products in that they provide more information to the participants on which to base their taste inferences (Woods & Spence, 2016; Woods, Marmolejo-Ramos, Velasco, & Spence, 2016). The possible explanations presented above might not necessarily be mutually exclusive. In the context of the two experiments reported, it is possible that the participants did not process the shapes as a unity (given that they were presented side by side). However, it is also common that visual attributes associated with food and drink products are presented in a more integrative fashion.

Figure 7. Representation of the five basic tastes by Jialin Deng. Figure reprinted from Spence, C., Wan, X., Woods, A., Velasco, C., Deng, J., Youssef, J., & Deroy, O. (2015). On tasty colours and colourful tastes? Assessing, explaining, and utilizing crossmodal correspondences between colours and basic tastes. *Flavour*, *4*:23.

Here, it is important to mention that there are generally multiple shapes properties associated with foods. These involve the shapes of the food themselves, but also of their packaging and corresponding design elements, just to mention a few. In that sense, we want to conclude with two questions: First, would it be possible to design a configuration of shape features (and perhaps other sensory elements) that best represents the tastes and flavours of specific foods so that one can increase the accuracy of taste/flavour inference by consumers? (see Figure 7, for an example). Second, when consumers judge a food's taste based on its visual characteristics, to what extend (or when) are such judgements based on their individual components or perhaps, a more general meaning derived from their perceptual grouping? Further research will be undoubtedly needed in order to clarify these questions. Here we present a first step in that direction, that is, we provide some initial evidence for the idea that over-and-above one-to-one taste-shape matches, people also associate taste and shape combinations in a non-random fashion.

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Appendix: Multiple correspondence analyses

An analysis of the results from the two experiments was undertaken using multiple correspondence analysis (MCA). This choice of analysis is made since Experiment 1 consists of three variables (Gender, Shape and Taste) and Experiment 2 consists of four variables (those of Experiment 1 plus Product). A comprehensive discussion of the various technical, practical, and historical aspects of correspondence analysis can be found in Greenacre (1984, 2017), Greenacre and Blasius (2006), and Beh and Lombardo (2012, 2014). There are many variations of correspondence analysis and one may consider Beh and Lombardo (Section 1.6.3) and Nishisato (2007, Section 3.3.3) for an extensive list of more than 30 members of the MCA “family”. MCA traditionally involves transforming a multi-way table into a Burt matrix, that is, a two-way super-diagonal matrix consisting of each pair-wise contingency table and diagonal matrices of each variable’s marginal totals. For the current analyses, a variation of MCA called joint correspondence analysis, or JCA (see Greenacre, 1988) was used. JCA is performed on the Burt matrix by first removing the information contained in the diagonal matrices of marginal totals (since such information is reflected in the pair-wise contingency tables). This provides, in most cases, a far superior visual summary of the association between the multiple variables than using the more traditional analysis of the Burt matrix. JCA was performed using the R package “ca” (see Nenadic & Greenacre, 2007, for a comprehensive overview of how to use the “ca” package to perform JCA).

Experiment 1

Figure 1 presents a two-dimensional summary of the association between Gender, Shape, and Taste. Since M and F are very close to the origin of Figure 1, the variable Gender does not appear to be an important contributor to the association structure between the three variables. The close proximity of these two points also shows that there is no difference in how the two genders are associated with the variables Taste and Shape. The results also show that the participants of the study could not distinguish well between whether circle or triangle was shown to them first, in the trials involving circle-triangle and triangle-circle. This is shown by the close proximity between circle-triangle and triangle-circle. Figure 1 also shows that the triangle-circle and circle-triangle configurations are strongly associated with “sweet and salty” and “sweet and sour”. Circle-circle is strongly associated with sweet. The results from Experiment 1 also show that participants had a similar preference for sour and “sour and bitter” tastes and that they were strongly associated with the triangle-triangle shape. While Figure 1 clearly shows how specific tastes and shapes are associated, it is key to keep in mind the quality of such a visual summary. By performing JCA, Figure 1 depicts 99.6% of the association between the three variables, which makes it an excellent visual display of the association between Gender, Shape and Taste.

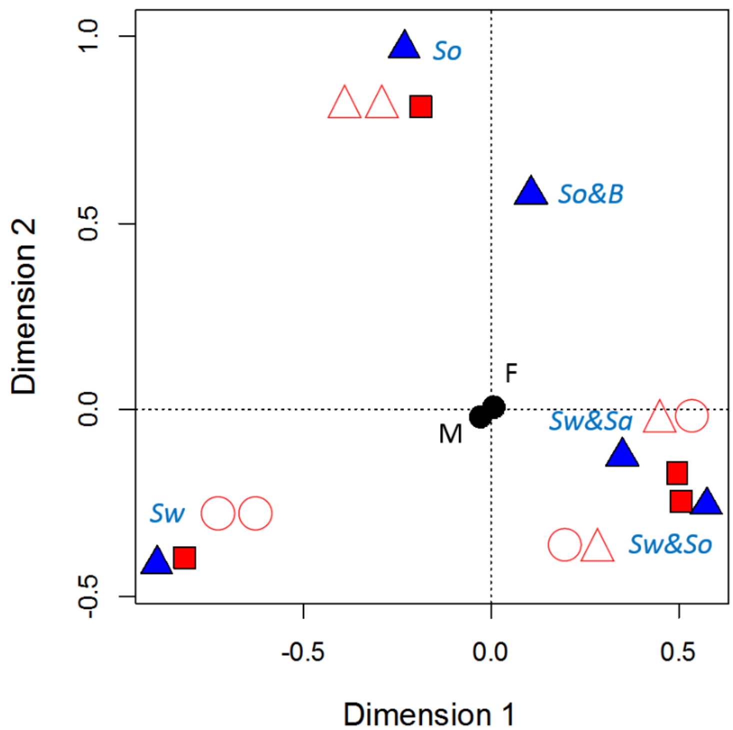

Figure 1. JCA of Gender (black circles. M = males; F = females), Shape (red squares) and Taste (blue triangles. So=sour, So&B= sour and bitter, Sw=sweet, Sw&Sa = sweet and salty, and Sw&So = sweet and sour) for Experiment 1.

Experiment 2

The inclusion of Product to the analysis for Experiment 2 provides further insight into the role of product type in the Gender, Shape, and Taste, associations. Figure 2 shows the JCA of the data from this experiment.

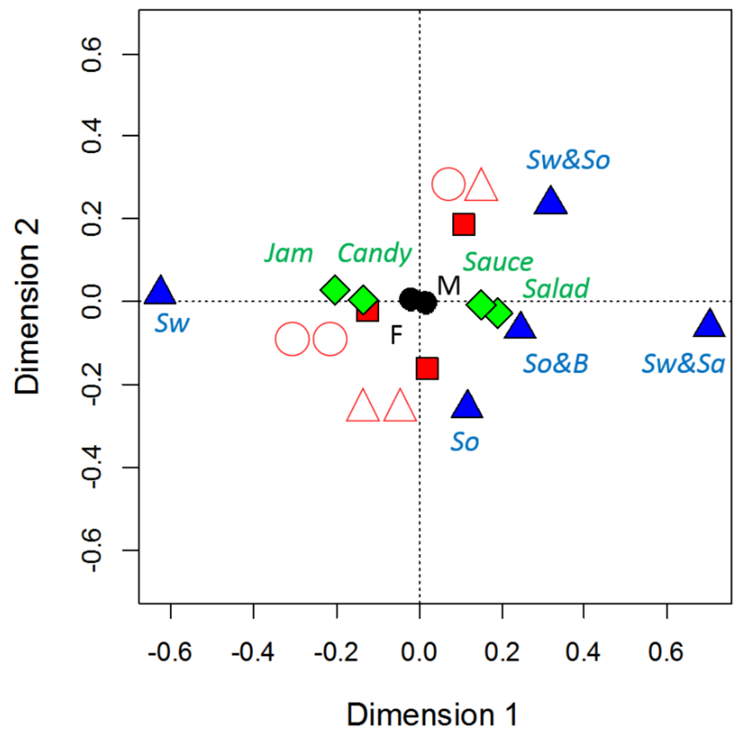

Figure 2. JCA of Gender (black circles. M = males; F = females), Shape (red squares), Taste (blue triangles. So=sour, So&B= sour and bitter, Sw=sweet, Sw&Sa = sweet and salty, and Sw&So = sweet and sour) and Product (green rhomboids) for Experiment 2.

This two-dimensional visual summary of the different variables, as in Figure 1 in this Appendix, shows that Gender does not play an important role in defining the association between the four variables. Figure 2 also shows that circle-circle is strongly associated with candy and Jam. Not surprisingly, therefore, these shapes and products are strongly linked to sweet taste. No particular shape is associated with salad and sauce but these products are strongly linked to "sour and bitter" taste. Similar to what Figure 1 in the Appendix indicated, Figure 2 shows that for the second experiment, sour is strongly associated with participants being shown the shape triangle-triangle combination. However, unlike Experiment 1, the inclusion of Product in Experiment 2 leads to a big difference in those participants who were given the circle-triangle combination and triangle-triangle combination. What is interesting here is that the results of the second experiment suggest that all five tastes included are perceived very differently by the participants. With the inclusion of a fourth variable in Experiment 2, the correspondence plot of Figure 2 visually depicts 85.4% of the association between the Gender, Shape, Taste and Product. While the reduction in the quality of Figure 2 when compared with Figure 1 in the Appendix can be accounted for by the inclusion of Product into the analysis, Figure 2 still provides an excellent visual summary of their association.

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