The semantic basis of taste-shape associations

Carlos Velasco, Andy T. Woods, Lawrence E. Marks, Adrian David Cheok, Charles Spence

Previous research shows that people systematically match tastes with shapes. Here, we assessed the extent to which matching taste and shape stimuli share a common semantic space and whether semantically congruent versus incongruent taste/shape associations can influence the speed with which people respond to both shapes and taste words. In Experiment 1, we used semantic differentiation to assess the semantic space of both taste words and shapes. The results suggest a common semantic space containing two principal components (seemingly potency and evaluation) and two principal clusters, one including round shapes and the taste word "sweet", and the other including angular shapes and the taste words "salty", "sour", and "bitter". The former cluster appears more positively-valenced whilst less potent than the latter. In Experiment 2, two speeded classification tasks assessed whether congruent versus incongruent mappings of stimuli and responses (e.g., sweet with round versus sweet with angular) would influence participants' speed of responding, both to shapes and to taste words. The results revealed an overall effect of congruence that was driven mostly when the participants had to classify shapes with taste words as responses. These results are consistent with previous evidence suggesting a close relation (or crossmodal correspondence) between tastes and shape curvature that may derive from common semantic coding, perhaps along the sensory-discriminative and hedonic dimensions.

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1366v1 | CC-BY 4.0 Open Access | rec: 12 Sep 2015, publ: 12 Sep 2015

RUNNING HEAD: TASTE-SHAPE SEMANTICS

THE SEMANTIC BASIS OF TASTE-SHAPE ASSOCIATIONS

Carlos Velasco[1, 2], Andy T. Woods[1, 3], Lawrence E. Marks[4],

Adrian David Cheok[2], & Charles Spence[1]

1. Crossmodal Research Laboratory,

Department of Experimental Psychology, Oxford University

2. Imagineering Institute, Iskandar, Malaysia

3. Xperiment, Surrey, United Kingdom.

4. John B. Pierce Laboratory, Department of Environmental Health Sciences,

Yale School of Public Health,

Department of Psychology, Yale University

DATE: SEPTEMBER, 2015

SUBMITTED TO: *PEERJ*

Correspondence concerning this article should be addressed to Dr. Carlos Velasco, Imagineering Institute, Anchor 5, Mall of Medini, No.4 Lebuh Medini Utara, Medini, Iskandar, Nusajaya, 79250, Johor, Malaysia. Tel: +60 07 509 6568 Fax: +60 07 509 6713. E-mail: carlos@imagineeringinstitute.org

ABSTRACT

Previous research shows that people systematically match tastes with shapes. Here, we assessed the extent to which matching taste and shape stimuli share a common semantic space and whether semantically congruent versus incongruent taste/shape associations can influence the speed with which people respond to both shapes and taste words. In Experiment 1, we used semantic differentiation to assess the semantic space of both taste words and shapes. The results suggest a common semantic space containing two principal components (seemingly potency and evaluation) and two principal clusters, one including round shapes and the taste word "sweet", and the other including angular shapes and the taste words "salty", "sour", and "bitter". The former cluster appears more positively-valenced whilst less potent than the latter. In Experiment 2, two speeded classification tasks assessed whether congruent versus incongruent mappings of stimuli and responses (e.g., sweet with round versus sweet with angular) would influence participants' speed of responding, both to shapes and to taste words. The results revealed an overall effect of congruence that was driven mostly when the participants had to classify shapes with taste words as responses. These results are consistent with previous evidence suggesting a close relation (or crossmodal correspondence) between tastes and shape curvature that may derive from common semantic coding, perhaps along the sensory-discriminative and hedonic dimensions.

KEYWORDS: CROSSMODAL CORRESPONDENCES, TASTES, SHAPES, SEMANTIC DIFFERENTIATION

"She laughed, a *laugh sweeter* than *honey*, with a *sound curving* and *zigzagging,* as if singing" - (Mo Yan, *Ball-Shaped Lightning*), cited by Yu (2003) p. 190.

Introduction

Several studies show that people systematically match both basic taste words and tastants with shapes that vary in terms of their curvature (see Spence & Deroy, 2013; Spence & Ngo, 2012, for reviews). Over the last few years, researchers, including ourselves, have studied crossmodal (taste-shape) correspondences and have provided some hints as to their underlying mechanisms (e.g., Velasco, Woods, Deroy, & Spence, 2015a; Velasco, Woods, Liu, & Spence, 2015c) and their effects on taste information processing more generally (e.g., Gal, Wheeler, & Shiv, 2007; Liang, Roy, Chen, & Zhang, 2013). Notably, while the way in which people match basic tastes with shapes seems reasonably well understood, the mechanisms that underlie crossmodal correspondences, as revealed in crossmodal (taste-shape) matches and congruency effects in perceptual processing are still to be clarified. In particular, research still needs to clarify when, how, and why the mechanism(s) that underlies taste-shape correspondences may influence the processing of taste (perceptual and linguistic) and shape information.

Velasco and his colleagues have shown how people match basic tastes and shapes. For example, a series of four experiments revealed that people associate sweet (both when presented as a word and as a tastant) with round shapes, and bitter, salty, and sour (as words) with more angular shapes (Velasco et al., 2015a, see also Ngo et al., 2013; Velasco, Salgado-Montejo, Marmolejo-Ramos, & Spence, 2014; Velasco, Woods, Hyndman, & Spence, 2015c). What is more, Velasco et al. (2015a) also reported that the more the participants liked the taste (but not a taste word), the rounder the shape matched to it (see also Bar & Neta, 2007, on curved objects preference) and suggested a hedonic mechanism to explain the crossmodal matching (see also Ghoshal, Boatwright, & Malika, 2015). This finding was subsequently replicated by Velasco et al. (2015c), who found that taste concentration can also affect shape matching, with more versus less intense tastants more likely matched to angular versus round shapes, respectively. Given the focus of the present study – on the semantic basis of taste word/shape correspondences, and associated congruence effects – the aforementioned findings are intriguing. Nevertheless, the presence of correlations alone do not suffice to show that a hedonic mechanism underpins the correspondences. Moreover, it is important to evaluate a wider range of intensities, given that the authors tested just two concentrations.

Importantly, other studies have also pointed to the idea that taste/shape correspondences may influence the processing of taste-information. For instance, Liang et al. (2013) assessed the influence of shapes on people's sensitivity to sweetness using near-threshold sucrose solutions. In their study, people rated round shapes as more pleasant. Further, presenting a round shape rather than an angular shape before tasting a sweet solution enhanced sweetness sensitivity (see also Gal, Wheeler, & Shiv, 2007; Stewart & Goss, 2013). Unfortunately, however, this study is the only of its kind, and further replication may be key (the effect is certainly specific and small), perhaps using everyday, suprathreshold, solutions. Moreover, there is a possible confound of response bias in the study, as Liang et al. did not attempt to control for the subjects' response criterion (e.g., apparently they did not include any 'blank,' water trials). Noteworthy, other studies have shown that the shape of a plate and food (when it is round as compared to angular) can influence participants' sweetness ratings of the food (resulting in people rating the food as tasting sweeter, see Fairhurst, Pritchard, Opsina, & Deroy, 2015, see also Piqueras-Fiszman, Alcaide, Roura, & Spence, 2012).

Here it is worth mentioning that, in spite of their perceptual basis, similarities across the senses also surface in language (e.g., see the quote at the beginning of the Introduction, Marks, 1978, 1996). With this in mind, we ask whether the potential hedonic- and intensity-related explanations/mediations of taste/shape correspondences may extend to taste words and, if so, whether they reflect: a perceptual process; a common connotative meaning (Walker, 2012; Walker, Walker, & Francis, 2013; see also Karwoski, Odbert, & Osgood, 1942, for an early example); or perhaps, a combination of the two (see also Walker & Walker, in press). According to the semantic coding hypothesis (SCH, see Martino & Marks, 2001), high level mechanisms that connect information across the senses may emerge from developmental experiences with various percepts that are coded into language, and that can affect multiple levels of human information processing. Consequently, crossmodal congruence effects can arise not only in the processing of perceptual stimuli, but also in the processing of verbal stimuli (Martino & Marks, 1999). While Liang et al. provided some evidence that congruent shapes can influence people's detection of sweet solutions presented at near threshold levels, we ask here whether the congruence of taste words and shapes can affect perceptual processing. As Marks (1978) pointed out, "According to the Oxford English Dictionary, 'sharp' applied first to touch, then subsequently to taste (ca. 1000), visual shape (1340), and hearing" (p. 190), indicating that shape-related words have been used to describe tastes for several centuries, and thereby perhaps some kind of implicit relation between shape and taste quality (see also Williams, 1976; Yu, 2003).

Here, we describe two experiments designed to assess whether shapes and taste words share a common semantic space and whether congruence between them can influence both taste words and shape information processing. Experiment 1 used semantic differentiation (Osgood, Suci, & Tannenbaum, 1957) to assess whether taste words and shapes share common dimensions of connotative meaning. Experiment 2 used a speeded classification task to assess whether taste/shape congruence affects the categorization of taste words and shapes. We hypothesized that taste words and shapes share a common semantic space to which previously reported associations will project, and that people will respond faster to the congruent versus incongruent pairings.

EXPERIMENT 1

Methods and materials

Participants. 102 participants (M age = 34.7 years, SD = 11.8, age range = 19-70, 51 females) took part in the study, online through the Adobe Flash based Xperiment software (http://www.xperiment.mobi). The participants were recruited using Amazon's Mechanical Turk in exchange for a payment of 1.50 USD (see Woods, Velasco, Levitan, Wan, & Spence 2015, for a methodological overview of internet-based research). All of the participants were based in the USA, and all agreed to take part in the study after reading a standard consent form. The experiment was reviewed and approved by the Central University Research Ethics Committee at the University of Oxford (MS-IDREC-C1-2014-056).

Apparatus and Materials. The images of four shapes (previously used by Köhler, 1929 and Ramachandran & Hubbard, 2001), including two angular and round (see Figure 1), as well as four taste words, namely bitter, sour, salty, and sweet, were used as the stimuli in this study. The taste words were presented in font Times New Roman 80.

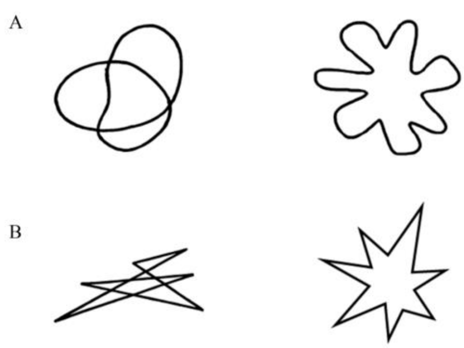


Figure 1. *Shape stimuli used in Experiment 1.*

Each stimulus was assessed using the semantic differential technique (SDT). Twelve pairs of polar adjectives were included, which were based on previous research using the SDT (Osgood, Suci, & Tannenbaum, 1957; Osgood, 1964). Each pair has been found to correlate with three bipolar dimensions, namely, evaluation, potency, and activity. The pairs of adjectives were: (1) nice-awful, (2) good-bad, (3) mild-harsh, (4) happy-sad (evaluation), (5) powerless-powerful, (6) weak-strong, (7) light-heavy, (8) shallow-deep (potency), (9) slow-fast, (10) quiet-noisy, (11) passive-active, and (12) dead-alive (activity). Each shape and taste stimulus was rated on a 100-point visual analogue scale (VAS), unmarked except for the adjectives, located outside the poles of the scale. Adjectives within the pairs 1, 3, 6, 8, 10, and 12 were reversed during in the experiment.

Procedure. At the beginning of the study, all participants were informed about the general aims and agreed to take part after reading a standard consent form. In the instructions, the participants were told that they would be presented with taste words or shapes and asked to rate them on a number of different scales. On each trial, one of the stimuli was presented in the middle of the screen together with a VAS (see the example in Figure 2). Trials were blocked by pair of adjectives (scales), and both order of trials and order of blocks were randomized across participants. In each block of adjective-defined scales, participants responded to the eight stimuli (four shapes and four taste words), giving rise to a total of 96 trials.

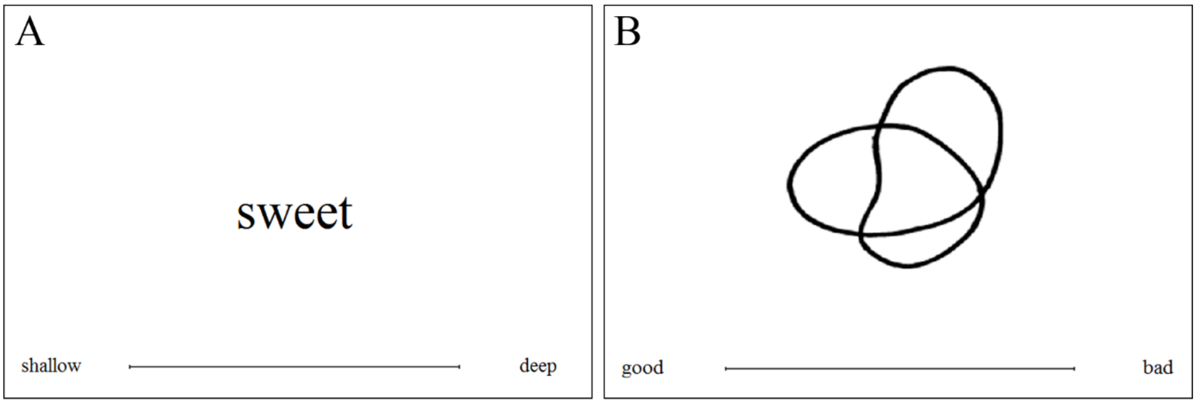


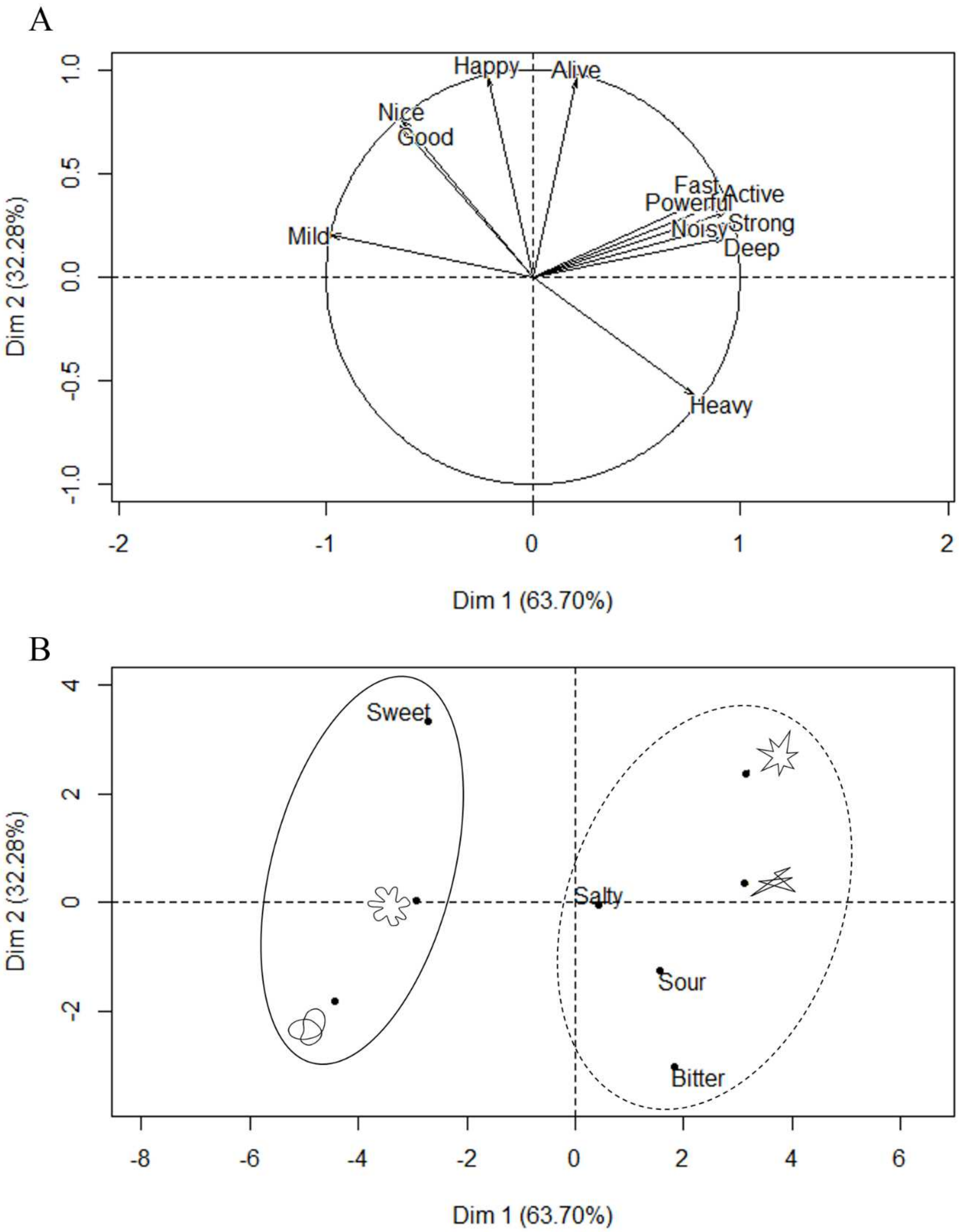
Figure 2. *Example of (A) a taste word and (B) a shape trial in Experiment 1.*

Analysis. A varimax-rotated principal component analysis (PCA) was used in order to define the principal dimensions arising from the different scale ratings of tastes and shapes. In addition, a hierarchical cluster analysis with Ward's method and squared Euclidean distance as the similarity measure was conducted in order to assess whether the different tastes and shapes would group as a function of common ratings in the scales used in Experiment 1. The data were aggregated as a function of dimensions and clusters and Wilcoxon signed-rank tests were performed to assess any difference between clusters as a function of dimensions. Effect sizes were calculated by means of Cliff's Delta as implemented in the {effsize} package (see https://cran.r-project.org/web/packages/effsize/effsize.pdf), in which 0 indicates the absence of an effect (the distributions overlap), while a value of -1 or 1 indicates a large effect (no overlap whatsoever; see Cliff, 1996).

Results and discussion

The principal component analysis (PCA, see Figure 3) revealed that two components had eigenvalues over Kaiser's criterion of 1 and, in combination, explained 95.98% of the variance. Table 1 shows the factor loadings after the varimax (orthogonal) rotation. Note that

182 the first and second components accounted for 59.01% and 36.89% of the variance,
183 respectively.



184
185 ***Figure 3.*** *Panel A presents the unrotated factor map of the polar scales in Experiment 1.*
186 *Note that only the label of the upper end of the scales is presented. Panel B presents the*
187 *unrotated factor map for the stimuli. The circles grouped the variables as a function of the*
188 *two clusters identified in the subsequent cluster analysis. Note that given that panel A and B*

show the unrotated visualizations, the percentages for each component vary slightly from those presented in Table 1.

<u>Table 1.</u> Varimax-rotated component matrix in Experiment 1 (see also Figure 4).

Adjectives	Component 1	Component 2
Passive - active	**.995**	-.018
Slow - fast	**.986**	.033
Powerless - powerful	**.986**	-.065
Weak - strong	**.980**	-.125
Shallow - deep	**.934**	-.182
Quiet - noisy	**.933**	-.184
Harsh - mild	**-.825**	.565
Sad - happy	.168	**.979**
Awful - nice	-.293	**.940**
Bad - good	-.311	**.919**
Light - heavy	.497	**-.825**
Dead - alive	.560	**.808**
Eigenvalues	7.09	4.43
% of variance	59.01%	36.89%

The dendrogram resulting from the hierarchical cluster analysis appears in Figure 4. Two major clusters are evident (see Table 2), one grouping round shapes with the taste word “sweet”, and another grouping angular shapes with the taste words salty”, “sour”, and “bitter”. These groupings reflect the tendency for stimuli in each cluster to receive similar ratings on the different semantic differential scales.

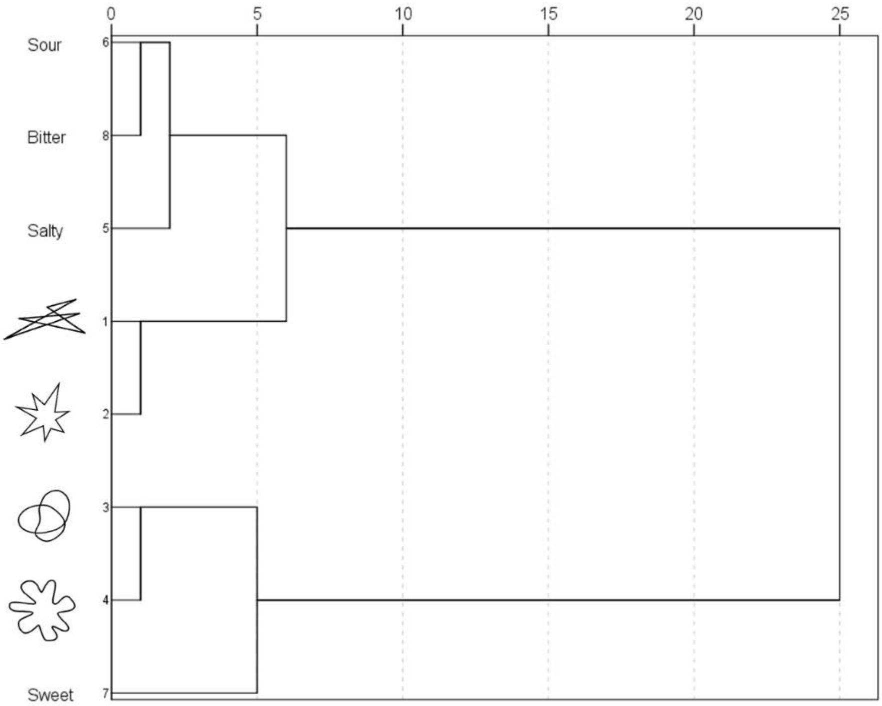


Figure 4. Dendrogram obtained by means of hierarchical cluster analysis in Experiment 1.

Table 2. Hierarchical Cluster Analysis in Experiment 1.

Stage	Cluster combined		Coefficients	Stage cluster first appears		Next stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	6	8	.000	0	0	4
2	1	2	.008	0	0	6
3	3	4	.031	0	0	5
4	5	6	.072	0	1	6
5	3	7	.219	3	0	7
6	1	5	.398	2	4	7
7	1	3	1.155	6	5	0

After identifying the two principal components and the two clusters, the data were aggregated as a function of dimension and cluster (Figure 5 summarizes the mean values). Note that the scores of harsh/mild and light/heavy were reversed as they correlated negatively with their respective dimensions. Wilcoxon signed-rank tests were performed in order to assess any difference between clusters on each dimension. The ratings on the first dimension of the stimuli in the second cluster were higher than those in the first cluster, ($p < .001$, Cliff's Delta = 0.96), whereas the ratings on the second dimension of the stimuli in the first cluster were lower than those in the second cluster, ($p < .001$, Cliff's Delta = 0.79). In other words, the round shapes and the taste word "sweet" were rated as more positively-valenced and less intense than the angular shapes and the taste words "salty", "sour", and "bitter".

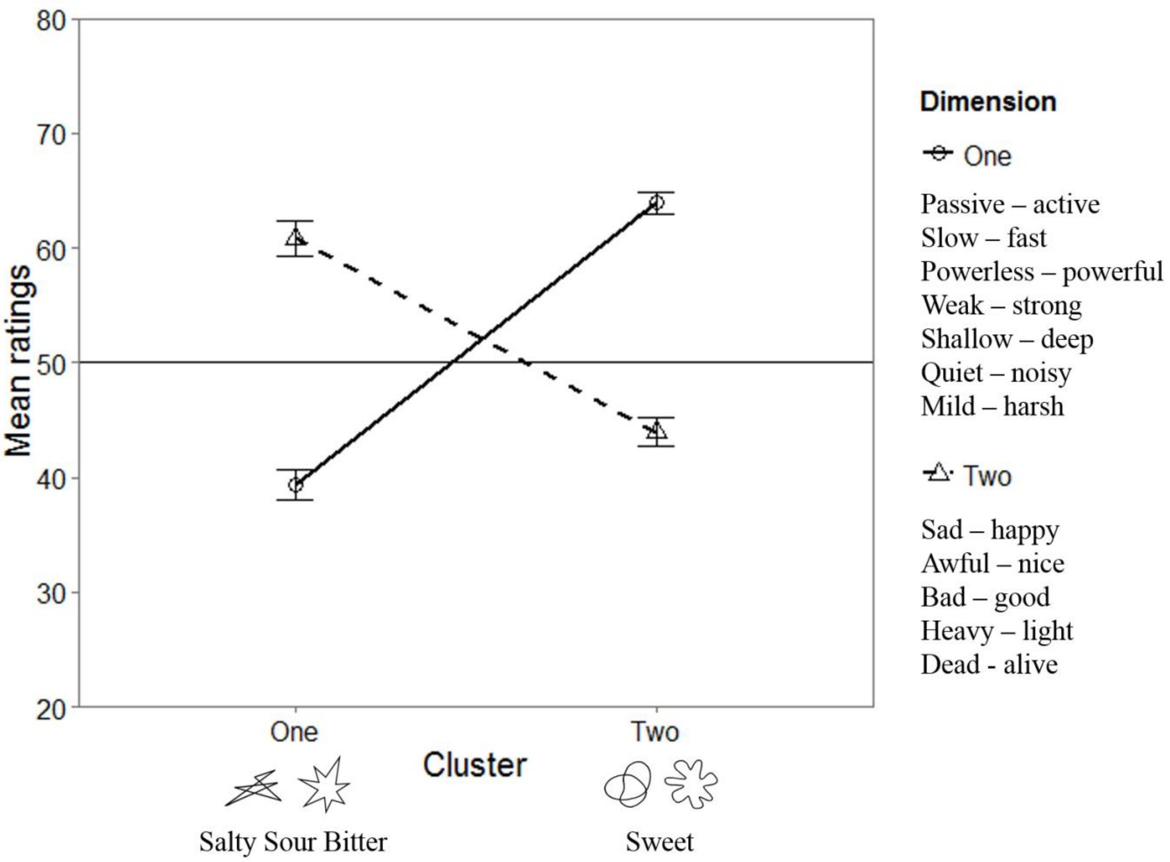


Figure 5. *Mean ratings for each cluster and dimension in Experiment 1. The error bars represent the standard error of the means.*

These results provide further support for the presence of an association between the word "sweet" and round shapes and the words "bitter", "salty", and "sour" and angular shapes (Velasco et al., 2015a-c). Moreover, the results also suggest that tastes and shapes share a semantic space or a set of implicit meanings, which is initially characterized by two main components. Indeed, a possibility is that these components reflect the two elements identified by Velasco et al. (2015a, b), namely hedonic value and intensity. Consistently, the results of Experiment 1 are in line with the idea that perceptual dimensions (e.g., sweet vs. sour, and fast vs. slow) differentiate between valence and arousal in specific ways (e.g., positive and negative and high and low arousal, respectively, see Cavanaugh, Maclnnis, & Weiss, 2015).

Experiment 1 established that taste words and visual shapes share dimensions of connotative meaning. Given this, Experiment 2 aimed to assess whether the crossmodal correspondence between taste words and shapes would produce congruence effects over-and-above those already reported with tastes per se (Liang et al., 2013), that is, by using linguistic taste stimuli. For this purpose, we designed a task in which a larger sample of participants (in order to compensate for potential hardware-related differences across participants and fewer trials, e.g., Woods et al., 2015) were given congruent or incongruent instructions about the mapping between taste words and shapes and were later asked to respond to shapes or taste words with taste words and shapes, respectively.

EXPERIMENT 2

Methods and materials

Participants. 253 participants (M age = 34.48 years, SD = 10.90, age range = 18 – 73 years, 138 females) took part in the study online and received a payment of 1.80 USD. All were based in the USA, and all agreed to take part in the study after reading a standard consent form.

Apparatus and Materials. The ten stimuli comprised four pairs of shapes (one round and one angular within each pair, 200 x 200 pixels each; see Figure 6A), plus two taste words “sweet” and “sour”. The taste words were again presented in font Times New Roman 80.

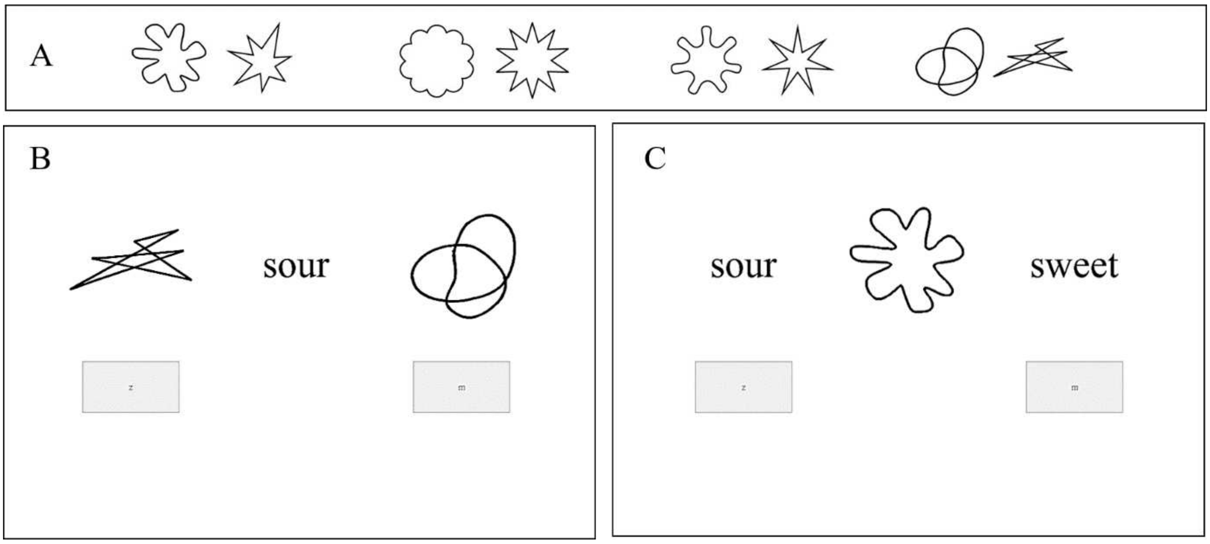


Figure 6. *Panel A presents a trial in the shape response task, Panel B of a trial in the taste response task, and Panel C presents the shape stimuli used in both tasks. Note that the shape stimuli are group in pairs as used as responses for the shape response task. The error bars represent the standard error of the means.*

Procedure. The participants took part in two tasks. In one of the tasks (*shape response*, see Figure 6A), the participants were presented the taste words “sweet” or “sour” (one at a time) and asked to respond with either an angular or round shape (i.e., pairs of shapes taken from Experiment 1, see Figure 6C). In the other task (*taste response*, see Figure 6B), the participants were presented the eight shape stimuli (one at a time) and were asked to respond with the taste words “sweet” or “sour”. Taste/shape congruence was manipulated in both tasks. That is, each task included a block of congruent trials and a block of incongruent trials. In the congruent (incongruent) block of the *taste response task*, the participants were asked to respond with the word sweet every time they saw a round (angular) shape and with the word sour every time they saw an angular (round) shape. In the congruent (incongruent) block of the *shape response task*, the participants were instructed to respond with round shapes every time they saw the word sweet (sour), and with angular shapes every time they saw the word sour (sweet). Note, however, that the possible responses were presented to the left or to the

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1366v1 | CC-BY 4.0 Open Access | rec: 12 Sep 2015, publ: 12 Sep 2015

right of the target stimulus, and the participants would have to press z or m, a function of the position of the correct response (see below).

Table 3 summarizes the experimental design. Each of the tasks included eight unique trials. In the *shape response task*, half of the trials required of the participants to respond to the word "sweet" and the other half to the word "sour". Moreover, four trials included the round shapes on the right and the angular on the left (two for "sweet" and two for "sour"); in the remaining four trials, the positioning was reversed. In the *taste response task*, the participants responded to the eight shapes with words "sweet" and "sour". The right-left position of "sweet" and "sour" was thus fully counterbalanced.

Table 3. Experimental design used in Experiment 2.

Task	Congruence	Instructions (stimuli mapping)	Stimuli	Responses	Unique trials	Repetitions
Shape response	Congruent	Sweet - round and sour - angular	Taste words (sweet or sour)	Angular or round shape (four pairs x 2)	8	X2
	Incongruent	Sweet - angular and sour - round			8	
Taste response	Congruent	Round - sweet and angular - sour	Shapes (eight shapes)	Sweet or sour	8	
	Incongruent	Round - sour and angular - sweet			8	

All eight unique trials were presented, once each for practice, before each block of congruent and incongruent trials in each task. Feedback came after each of the practice trials with the word "correct" or "wrong" presented for 0.5 s. Immediately after the practice trials, the participants proceeded to the experimental trials of the block. All eight unique trials were presented twice, giving rise to a total of 16 trials per block and 64 for the whole experiment. To prevent the participants from responding to right or left position as opposed to sweet/sour or angular/round, 8 trials in each block mapped to one response ("sweet"/"sour", angular/round) to the z key, and in the other 8 trials to the m key.

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1366v1 | CC-BY 4.0 Open Access | rec: 12 Sep 2015, publ: 12 Sep 2015

Analyses. Both accuracy and RTs were analysed as a function of task and congruence. Accuracy and RTs were analysed by means of 2 × 2 analysis of variance-type statistics (ATS; Erceg-Hurn & Mirosevich, 2008) with the factors of task and congruence. The analyses were performed in R Statistical Software, as implemented in the {nparLD} package (Noguchi, Gel, Brunner, & Konietschke, 2012). The significant main effects and interactions were further analysed with the Wilcoxon signed-rank test to which Bonferroni corrections were also applied. Effect sizes were also calculated by means of Cliff's Delta.

Results and discussion

Accuracy. Data from those participants failing to respond accurately on more than 60% of the trials were excluded from the analyses (a total of 14 participants). Whilst there was a significant main effect of task, $F_{ATS}(1, \infty) = 14.76$, $p < .001$, the effect of congruence was not significant, $F_{ATS}(1, \infty) = 0.48$, $p = .488$, nor was the interaction between task and congruence, $F_{ATS}(1, \infty) = 1.52$, $p = .217$. Wilcoxon signed-rank test revealed that the participants were more accurate in the task in which they had to respond with taste words rather than shapes ($p = .001$, Cliff's Delta = 0.15). Figure 7A summarizes the results.

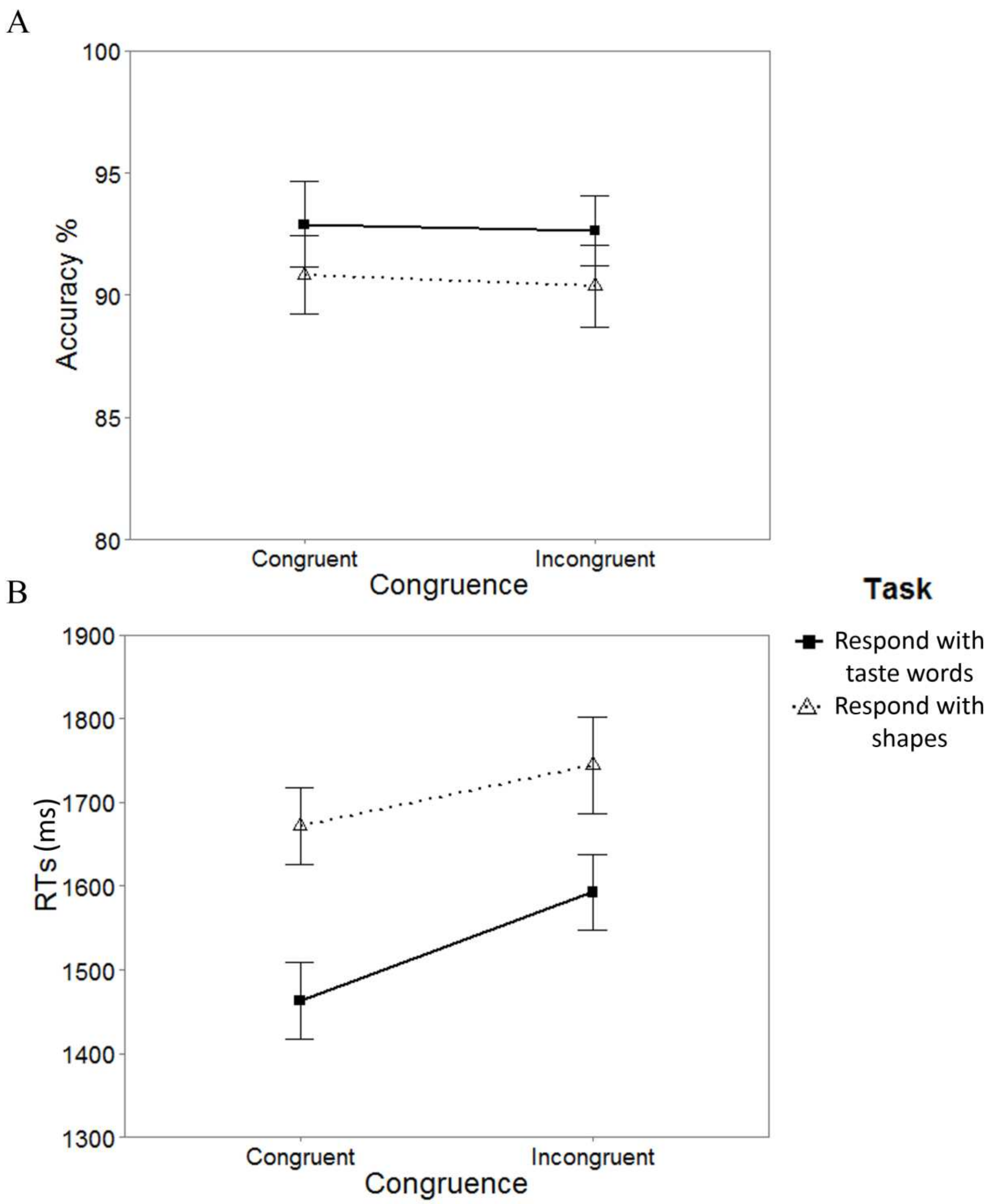


Figure 7. *Summary of the results of Experiment 2. Panel A presents accuracy and panel B presents the mean reaction times (RTs) in both tasks as a function of congruence. The error bars represent the standard error of the means.*

RTs. The ANOVA-type statistic revealed a significant effect of task, F_{ATS} (1, ∞) = 121.31, $p <$ .001, congruence, F_{ATS} (1, ∞) = 13.71, $p <$ .001, and a borderline significant trend in the interaction between task and congruence, F_{ATS} (1, ∞) = 3.38, p = 0.066. The participants responded more rapidly in the task in which they responded with taste words rather than shapes ($p < .001$, Cliff's Delta = 0.27). Moreover, participants also responded more rapidly on the congruent than the incongruent trials ($p < .001$, Cliff's Delta = 0.12). Although the interaction between task and congruence failed to reach significance, we proceeded to analysed whether the effect was nevertheless similar in the two tasks. The participants responded more rapidly to the congruent trials than the incongruent trials when they had to respond with taste words ($p < .001$, Cliff's Delta = 0.14). However, this effect of congruence was not as pronounced, either numerically or statistically, as it was when the participants had to respond with shape words ($p = .09$, Cliff's Delta = .07). See Figure 7B, for a summary of the results.

The results of Experiment 2 provide evidence for the idea that taste/shape correspondences can indeed produce congruence effects even in the absence of tastants, but just with shapes and taste words. It is worth mentioning, though, that there was a difference across tasks too: Participants were more accurate, and responded more rapidly, in the *taste response task* than in the *shape response task*. Moreover, an overall congruence effect was observed across tasks. However, the effect seems more pronounced for the *taste response task*. The results of Experiment 2 extend previous studies assessing taste/shape congruence (e.g., Fairhurst et al., 2015; Liang et al., 2013) to taste word/shape congruence.

GENERAL DISCUSSION

Two experiments aimed to assess, first, whether basic taste words and shapes share a semantic space – a set of implicit meanings – that may contribute to the correspondences between these stimuli, and, second, whether these crossmodal correspondences can induce congruence effects when linguistic stimuli rather than tastants are used. Experiment 1 revealed that taste words and shapes do share a semantic space, which is mainly characterized by dimensions related to intensity and hedonic value. Moreover, consistent with previous research (Spence & Deroy, 2013, for a review), specific tastes and shapes clustered, "sweet" with round shape and "bitter", "salty", and "sour" with angular shape. Experiment 2 introduced a task in which people were instructed to respond either to shapes with taste words or to taste words with shapes, under conditions that defined the stimulus-response relations either congruently (e.g., respond round to "sweet") or incongruently (e.g., respond angular to "sweet"). Both task and congruence mattered: First, the participants were more accurate and faster when responding to taste words with shapes than when responding to shapes with taste words. And second, the participants responded more rapidly with congruent than with incongruent pairings of stimuli and responses, although this effect of congruence was stronger when the participants responded with taste words than with shapes.

One question that deserves to be asked, relating to Experiment 1, is whether the semantic basis of taste words and shapes may also apply to tastants. Research conducted by Velasco et al. (2015a) demonstrated that the ways in which people match taste words and tastants to shapes follow similar patterns (as one might have expected)[1]. Sweet tends to associate with round shapes whilst bitter, sour, salty, and salty associate with angular shapes. One important direction for future research concerns the evaluation of the semantic space of both taste words and tastants. For example, one could examine the common semantic space for taste words and tastes by running either a semantic differentiation study or a similarity rating experiment on a stimulus set that included both tastes and taste words.

[1] This is of particular relevance given the fact that previous research has documented the importance of some non-semantic features of taste words (e.g., typeface features, see Velasco et al., 2015b) and/or the implicit vocalization, articulation/kinesthesis, and/or sound imagery in conveying meaning (e.g., Ngo et al., 2013). For example, one may argue that it is not the word "sweet" but rather its sound symbolic meaning, which guides its matching to round shapes. While we cannot rule out all the specific interactions between the aforesaid variables, it is known that tastants and taste words are similarly matched to shapes varying in terms of their curvature (Velasco et al., 2015a).

Although the present research focused on taste words and shapes, it is worth considering whether the results would be similar if we had used shape words instead of shapes. Presumably, shape words would operate semantically like shapes *per se*, at least to the extent that taste words operate semantically like tastes (although in both cases there may be some interesting differences between the connotative meanings of perceptual stimuli and the analogous words, as Osgood, 1960, suggested with colors and color words). In some instances, words may connote ‘prototypes’ that cannot easily be realized in particular stimuli. Such a matter may be an interesting direction for future research.

Nearly two decades ago, Marks (1996) highlighted that “*The correspondences between primary perceptual meanings and secondary linguistic ones need not be perfect – language and perception do not necessarily carve the world up in precisely the same way (cf. Miller & Johnson-Laird, 1976) – but the connections are nevertheless strong*” (p. 49). The results of Experiment 2 extend previous work on taste/shape associations and taste and shape information processing to taste words and shapes. As noted before, in the English language, for example, the use of shape-related words such as “sharp” to describe tastes has a long history (Marks, 1978; Williams, 1976; Yu, 2003). This said, even though the effects found in Experiment 2 were small, so too were earlier taste/shape congruence effects reported with perceptual stimuli (Liang et al., 2013; note, however, that comparing effect sizes across experimental paradigms is not an easy task given their different nature), and these effects prove noteworthy given the seemingly unrelated nature of basic taste words and shapes.

How to interpret the fact that taste word/shape correspondences product congruence effects? In order to answer this question, it is important to highlight the fact that the tasks included in Experiment 2 required the participants to learn specific associations (either congruent or incongruent). This said, it is reasonable to assert that there is an implicit relation between specific taste words and shape curvature. How is such implicit relationship built? Results of

Experiment 1, together with those of Velasco et al. (2015a, b), provide some clues in support of a hedonic association, and preliminary experimental data for a sensory-discriminative association (see also e.g., Marks, 1978, 2013; Parise & Spence, 2013; Spence, 2011, for reviews on possible mechanisms underlying crossmodal correspondences). Given that intensity and hedonics are also influenced by other low-level visual properties and shape aesthetic features (e.g., Palmer, Schloss, & Sammartino, 2013), which influence taste/shape correspondences (Salgado-Montejo et al., 2015), it should be reasonable to extend the present results to other visual attributes (e.g., shape symmetry).

The congruence effect in Experiment 2 was more pronounced in the *taste response task* than in the *shape response task.* This result is particularly intriguing given the fact that previous research has suggested that crossmodal correspondences tend to be bidirectional, that is, people match stimulus dimensions from two sense modalities in both directions (e.g., Parise & Spence, 2013). Perhaps, such bi-directionality works differently with linguistic as compared to perceptual stimuli. Moreover, the present asymmetry may be a product of the more varied response options in the task in which participants responded with shapes (four pairs of shapes versus two taste words). Nonetheless, it seems clear that people respond differently to tastes and shapes when the mappings are consistent rather than inconsistent with the correspondence – an additional piece of evidence to suggest that taste words and shapes share an abstract semantic network and that the existence of crossmodally shared locations in semantic space *ipso facto* define or characterize crossmodal congruence.

REFERENCES

Bar M, Neta M. 2006. Humans prefer curved visual objects. *Psychological Science* 17:645-648. DOI: 10.1111/j.1467-9280.2006.01759.x.

Cavanaugh LA, MacInnis DJ, Weiss, AM. 2015. Perceptual dimensions differentiate emotions. *Cognition and Emotion* (ahead-of-print): 1-16. DOI: 10.1080/02699931.2015.1070119.

Cliff N. 1996. Answering ordinal questions with ordinal data using ordinal statistics. *Multivariate Behavioral Research* 31: 331-350. DOI: 10.1207/s15327906mbr3103_4.

Erceg-Hurn, DM, Mirosevich VM. 2008. Modern robust statistical methods: An easy way to maximize the accuracy and power of your research. *American Psychologist* 63:591-601. DOI: 10.1037/0003-066X.63.7.591.

Fairhurst MT, Pritchard D, Ospina D, Deroy O. 2015. Bouba-Kiki in the plate: Combining crossmodal correspondences to change flavour experience. *Flavour* 4: 22. DOI: 10.1186/s13411-015-0032-2.

Ghoshal T, Boatwright P, Malika M. 2015. Curvature from all angles: An integrative review and implications for product design. In: Batra R, Seifert C, Brei D, eds. *The psychology of design: Creating consumer appeal*. New York, NY: Routledge, 91-105.

Karwoski TF, Odbert HS, Osgood CE. 1942. Studies in synesthetic thinking: II. The role of form in visual responses to music. *The Journal of General Psychology* 26: 199-222. DOI: 10.1080/00221309.1942.10545166.

Köhler W. 1929. *Gestalt psychology*. New York, NY: Liveright

Liang P, Roy S, Chen ML, Zhang GH. 2013. Visual influence of shapes and semantic familiarity on human sweet sensitivity. *Behavioural Brain Research* 253: 42-47. DOI: 10.1016/j.bbr.2013.07.001.

Marks LE. 1978. *The unity of the senses: Interrelations among the modalities*. New York, NY: Academic Press.

Marks LE. 1996. On perceptual metaphors. *Metaphor and Symbol* 11: 39-66. DOI: 10.1207/s15327868ms1101_3.

Marks LE. 2013. Weak synaesthesia in perception and language. In Simner J, Hubbard E, eds. *The Oxford handbook of synaesthesia*. Oxford, UK: Oxford University Press, 761-789.

Marks LE, Mulvenna CM. 2013. Synesthesia, at and near its borders. *Frontiers in Psychology* 4: 651. DOI: 10.3389/fpsyg.2013.00651.

Martino G, Marks, LE. 1999. Perceptual and linguistic interactions in speeded classification: Tests of the semantic coding hypothesis. *Perception* 28: 903-924. DOI: 10.1068/p2866.

Martino G, & Marks LE. 2001. Synesthesia: Strong and weak. *Current Directions in Psychological Science* 10: 61-65. DOI: 10.1111/1467-8721.00116.

Ngo MK, Velasco C, Salgado A, Boehm E, O'Neill D, Spence C. 2013. Assessing crossmodal correspondences in exotic fruit juices: The case of shape and sound symbolism. *Food Quality and Preference* 28: 361-369. DOI: 10.1016/j.foodqual.2012.10.004.

Noguchi K, Gel YR, Brunner E, Konietschke F. 2012. nparLD: An R Software Package for the nonparametric analysis of longitudinal data in factorial experiments. *Journal of Statistical Software* 50: 1-23.

Osgood CE. 1960. The cross-cultural generality of visual-verbal synesthetic tendencies. *Behavioral Science* 5: 146-169. DOI: 10.1002/bs.3830050204.

Osgood CE. 1964. Semantic differential technique in the comparative study of cultures. *American Anthropologist* 66: 171-200. DOI: 10.1525/aa.1964.66.3.02a00880.

Osgood CE, Suci GJ, Tannenbaum PH. 1957. *The measurement of meaning*. Urbana, IL: University of Illinois Press.

Palmer SE, Schloss KB, Sammartino J. 2013. Visual aesthetics and human preference. *Annual Review of Psychology* 64: 77-107. DOI: 10.1146/annurev-psych-120710-100504.

Parise C, Spence C. 2013. Audiovisual cross-modal correspondences in the general population. In Simner J, Hubbard E, eds., *The Oxford handbook of synaesthesia*. Oxford, UK: Oxford University Press, 790-815.

Ramachandran VS, Hubbard EM. 2001. Synaesthesia--a window into perception, thought and language. *Journal of Consciousness Studies* 8: 3-34.

Salgado-Montejo A, Alvarado J, Velasco C, Salgado CJ, Hasse K, Spence C. 2015. The sweetest thing: The influence of angularity, symmetry, and number of elements on shape-valence and shape-taste matches. *Frontiers in Psychology* 6: 1382. DOI: 10.3389/fpsyg.2015.01382.

Salgado-Montejo A, Velasco C, Olier S, Alvarado J, Spence C. 2014. Love for logos: Evaluating the congruency between Brand symbols and typefaces and their relation to emotional words. *Journal of Brand Management* 21: 635-649. DOI: 10.1057/bm.2014.29.

Spence C. 2011. Crossmodal correspondences: A tutorial review. *Attention, Perception, & Psychophysics 73*: 971-995. DOI: 10.3758/s13414-010-0073-7.

Spence C, Ngo MK. 2012. Assessing the shape symbolism of the taste, flavour, and texture of foods and beverages. *Flavour* 1: 12. DOI: 10.1186/2044-7248-1-12.

Velasco C, Salgado-Montejo A, Marmolejo-Ramos F, Spence C. 2014. Predictive packaging design: Tasting shapes, typographies, names, and sounds. *Food Quality and Preference* 34: 88-95. DOI: 10.1016/j.foodqual.2013.12.005.

Velasco C, Woods A, Deroy O, Spence C. 2015a. Hedonic mediation of the crossmodal correspondence between taste and shape. *Food Quality and Preference* 41: 151-158. DOI: 10.1016/j.foodqual.2014.11.010

Velasco C, Woods AT, Hyndman S, Spence C. 2015b. The taste of typeface. *i-Perception* 6: 1-10. DOI: 10.1177/2041669515593040.

Velasco C, Woods AT, Liu J, Spence C. 2015c. Assessing the role of taste intensity and hedonics in taste–shape correspondences. *Multisensory Research*. DOI: 10.1163/22134808-00002489

Walker P. 2012. Cross-sensory correspondences and cross talk between dimensions of connotative meaning: Visual angularity is hard, high-pitched, and bright. *Attention, Perception, & Psychophysics* 74: 1792-1809. DOI: 10.3758/s13414-012-0341-9.

Walker L, Walker P. in press. Cross-sensory mapping of feature values in the size-brightness correspondence can be more relative than absolute. *Journal of Experimental Psychology: Human Perception and Performance.*

Walker L, Walker P, Francis B. 2013. A common scheme for cross-sensory correspondences across stimulus dimensions. *Perception* 41: 1186-1192. DOI: 10.1068/p7149.

Wan X, Woods AT, van den Bosch J, McKenzie KJ, Velasco C, Spence C. 2014. Cross-cultural differences in crossmodal correspondences between basic tastes and visual features. *Frontiers in Psychology* 5: 1365. DOI: 10.3389/fpsyg.2014.01365

Williams JM. 1976. Synaesthetic adjectives: A possible law of semantic change. *Language* 52: 461-478. DOI: 10.2307/412571.

Woods AT, Velasco C, Levitan CA, Wan X, Spence C. 2015. Conducting perception research over the internet: A tutorial review. *PeerJ* 3: e1058. DOI: 10.7717/peerj.1058.

Yu N. 2003. Synesthetic metaphor: A cognitive perspective. *Journal of Literary Semantics* 32: 19-34. DOI: 10.1515/jlse.2003.001.