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Spontaneous crossmodal correspondences grounded in contexts

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Abstract

Thoughts and associations are spontaneously generated and situated. A growing body of research on crossmodal correspondences has revealed that individuals tend to associate information across sensory modalities. However, most of the findings have been based on restricted sensory pairs/items and the role of context remains largely unexplored. Relying on crossmodal correspondence studies and the theory of situated conceptualization, the present study aimed to study spontaneous crossmodal correspondences and the role of context (background situations, culture) in modulating them. Japanese and British participants (n = 604) were presented with shape stimuli (rounder and more angular) and spontaneously generated words describing the stimuli in different contexts (geometric shapes, logo in food packaging, and logo in non-food products). The results demonstrated that individuals spontaneously associate shape features with different senses, something that is influenced by context (background situations, culture). Geometric shapes were associated with visual and auditory descriptors, while shapes in the food context were linked with chemosensory (olfactory and taste) descriptors. Moreover, Japanese participants were more likely to generate touch descriptors, while British participants were more likely to use auditory descriptors. Together, our findings reveal how multisensory associations are spontaneously generated and how these associations are grounded in context.

Keywords: Crossmodal correspondences; Grounded cognition; Sensory linguistics; Food

Introduction

Individuals tend to associate information across different senses in specific ways, a phenomenon that has been termed crossmodal correspondences (Spence, 2011). A growing body of evidence has shown that visual, auditory, olfactory, haptic, and gustatory stimuli are matched (or associated) in nonrandom ways (e.g., Spence, 2011). Some initial evidence of crossmodal correspondences was reported about a century ago (Köhler, 1947), with the bouba-kiki effect. This indicates that individuals tend to match the nonsense words *bouba* and *kiki* with round and spiky shapes, respectively.

Most crossmodal correspondence studies have been based on restricted sensory pairs and items. Typically, participants were asked to match a sensory attribute (e.g., sweet taste) with a different single attribute (e.g., color) in a restricted range (e.g., red and green) (Spence et al., 2015). The findings in crossmodal correspondence studies are robust when the task involves subjective matching (e.g., Spence, 2011; Velasco et al., 2016). However, negative or non-straightforward findings have been reported in the case of downstream consequences of crossmodal correspondences (e.g., Otterbring et al., 2022; Wang et al., 2017).

this does not necessarily mean that individuals spontaneously associate information across different senses. When participants are given a stimulus (e.g., sweet taste) and are asked to match it to a range of other stimuli (e.g., shapes varying in curvature), they are primed to think about the first stimulus given to the participants (e.g., sweet taste). This restricts the associations to those instances in which individuals consider the first stimulus (e.g., sweet taste) but do not reveal much in terms of what it evokes spontaneously in terms of other sensory modalities (e.g., other than sweet tastes).

It is essential to understand the existence of spontaneous crossmodal correspondences. In naturalistic settings, individuals are not given options to answer which sense is matched with a different sense. Rather, they are exposed to a given sensory stimulus, and then sensory associations may come to mind, something that may be constrained by context (e.g., food context) or task (e.g., search for something). Given that few studies have investigated spontaneous crossmodal correspondences (see Karwoske, Odbert, & Osgood, 1942), we studied how a particular sensory stimulus may evoke associations with information in other senses. We employed a data-driven approach using a word-association technique (Collova et al., 2019). This allows us to obtain participants' unconstrained descriptors (or associations) of a sense without imposing a priori assumptions on the participants.

Relying on the theory of situated conceptualization (Barsalou, 2009), we assume that spontaneous crossmodal correspondences are grounded in contexts (e.g., background situations, cultural contexts). According to the theory, the brain is a situated processing architecture and situations are fundamental to cognition (Barsalou, 2009). When people perceive a stimulus, they perceived the stimulus along with the background situations is perceived (Barsalou, 2009). Given the theory of situated conceptualization, it seems natural that individuals associate a sensory stimulus with different sensory concepts depending on the context. When individuals see shape features in a food context (e.g., shapes on food packaging), the relevant sensory imagery in the food context (e.g., taste, smell) appears to be evoked. In contrast, when seeing the same shape features without the food context (e.g., shapes on t-shirts), individuals may not generate words describing taste, smell, and touch.

The theory of situated conceptualization also suggests that culture can modulate spontaneous sensory associations. Culture can be regarded as a factor of situated cognition (Oyserman, 2016). Studies on sensory linguistics have suggested that different culture has distinct accessibilities to sensory concepts (Levinson & Majid, 2014; Lynott et al., 2020; Majid et al., 2018; Strik Lievers & Winter, 2018; Uchida et al., 2021). Vision and audition are overrepresented, and chemical senses (smell and tastes) appear to be underrepresented in English and related languages (Levinson & Majid, 2014; Lynott et al., 2020; Strik Lievers & Winter, 2018). In contrast, in Japan, touch-related words are predominantly represented in the form of ideophones (Uchida et al., 2021). This indicates that sensory descriptors are also grounded in culture, and different spontaneous sensory associations may be observed depending on the culture.

The present study aimed to reveal spontaneous crossmodal correspondences and how contexts modulate sensory associations. Japanese and British participants saw visual stimuli (rounder and angular shapes) and spontaneously generated words describing them in different contexts (geometric shapes, a logo in food packaging, and a logo in non-food products). We used shape stimuli (rounder and more angular) for the participants to perceive. From the classic work on the bouba-kiki effect (Köhler, 1947), studies on crossmodal correspondences have demonstrated that shape features (round and angular) are associated with various senses (e.g., Spence et al., 2013; Velasco et al., 2016). Moreover, shape features have been used in different contexts, such as food (e.g., food packaging) and non-food products (e.g., logo design).

Method

Design and Participants

The study followed a one-way between-participants design with three levels: geometric, food, and non-food stimulus categories. Data were collected from 306 Japanese participants (130 women, 169 men, seven prefer not to say; mean age = 41.68

years; SD = 10.14) and 298 British participants (215 women, 81 men, two prefer not to say; mean age = 34.30 years; SD = 12.59). The participants were randomly allocated to one of three conditions in Japan (geometric: n = 107; food: n = 96; and non-food: n = 103) and the UK (geometric: n = 106; food: n = 87; and non-food: n = 105). The sample size was based on recent studies using word association techniques (Collova et al., 2019). A priori sample size calculation was not formally conducted because there was no prior data on estimating the likelihood of spontaneous association of visual stimuli with other sensory descriptors. We determined a sample size of 300 participants for each country and obtained a relatively larger size of data for analyses (the number of sensory descriptors in Japanese and British participants was 1,155 and 609, respectively). Japanese participants were recruited from Lancers, and British participants were recruited from Prolific. All participants completed the survey on Qualtrics and received monetary compensation for their time. All the studies described herein were approved by the ethics committee of Miyagi University.

Procedures

The participants saw a set of stimuli consisting of geometric shapes, shapes on food packaging, or shapes on t-shirts. The participants were instructed as follows:

“Please write down four words, descriptors, associations, thoughts, or feelings that come to mind after having seen this image” (Collova et al., 2019). In total, the participants saw four stimuli (two round shapes, two angular shapes; Figure 1) and provided descriptors for each stimulus. The order of shape stimuli was randomized.

Data Categorizations

In total, Japanese and British participants provided 1,712 and 1,969 descriptors for geometric shapes, 1,536 and 1,392 for food products, and 1,648 and 1,680 for non-food products, respectively.

First, the descriptors were categorized into sensory (e.g., angular and soft), and the other two categories (emotions/feelings; e.g., relaxed and intense, and others; e.g., cloud and flower) for each context (geometry, food, non-food), although we specifically focus on sensory terms. For the data of Japanese participants, two raters independently classified the descriptors into each category, with a later mutual discussion resolving any disagreement. For the data of British participants, two raters independently classified the descriptors into each category, and the third rater resolved any disagreement. When the third rater could not resolve the disagreements, the researcher solved it.

The results of the inter-rater reliability showed that Cohen's κ revealed substantial agreement between the two raters in all categories in Japan (geometric; $\kappa = .747$, $p < .001$; food product: $\kappa = .657$, $p < .001$; non-food product; $\kappa = .649$, $p < .001$) and the UK (geometric; $\kappa = .515$, $p < .001$; food product: $\kappa = .628$, $p < .001$; non-food product: $\kappa = .679$, $p < .001$). Based on this classification, descriptors were classified by sensory (n = 1155 for Japan; n = 609 for the UK), emotion/feelings (n = 1243 for Japan; n = 1648 for UK), and others (n = 2498 for Japan; n = 2511 for UK). Since we focused on spontaneous crossmodal correspondences, only data in the "sensory" category applied to our research. The data in other categories were used only for the data categorization process to discriminate variables of interest (*sensory*) and irrelevant ones (*emotions*, *others*). Therefore, the data in the other two categories will not be used elsewhere.

The sensory descriptors were further classified into five major sensory modalities (vision, audition, smell, touch, and taste) in the same way (i.e., the same raters classified). We also calculated the inter-rater reliability of the sensory descriptors for Japanese and British participants. Cohen's κ revealed almost perfect agreement between the two raters for sensory descriptors of all conditions in Japan (geometric: $\kappa = .809$, $p < .001$; food product: $\kappa = .854$, $p < .001$; non-food product: $\kappa = .855$, $p < .001$).

Likewise, Cohen's κ revealed almost perfect agreement between the two coders for all conditions in the UK (geometric: $\kappa = 1.000$, $p < .001$; food product: $\kappa = .891$, $p < .001$; non-food product: $\kappa = 1.000$, $p < .001$).

Results of Spontaneous Sensory Associations in Japan and the UK

To determine how people in Japan and the UK spontaneously associated visual stimuli with other senses, chi-squared tests were conducted for Japan and the UK data. The data of the conditions (geometry, food, and non-food) and shapes (round and angular) were collapsed. The sensory associations for Japanese ($\chi 2_4 = 972.87$, $p < .001$, *Cramer's V* = 0.459) and the UK ($\chi 2_4 = 438.71$, $p < .001$, *Cramer's V* = 0.424) were not uniformly distributed (Table 1; Figure 2). For the Japanese data, the analysis of standardized residuals (SR) revealed that vision (SR = 24.05) and touch (SR = 9.78) were over-overrepresented, while audition (SR = -16.77) and smell (SR = -16.11) were underrepresented (all *ps* <.001). No significant difference was found in taste (SR = -0.96, $p = .33$). For the UK data, vision (SR = 18.96) was overrepresented, while smell (SR = -11.93), touch (SR = -5.55), and taste (SR = -3.42) were underrepresented (all *ps* <.001). No significant difference was found in audition (SR = 1.95, $p = .052$).

Results of Contextual Differences in Spontaneous Sensory Associations in Japan and the UK

To determine whether the proportions of selection for sensory descriptors differed among the conditions (Table 2), Fisher's exact test for count data was conducted with post-hoc pairwise comparisons using the Holm procedure. The results from the combined sample (Japan + the UK) and frequently mentioned words are shown in Appendices B to D.

Geometry versus Food

The results demonstrated significant differences in the proportions of sensory descriptors between geometric shapes and food products (Japan: $p < .001$; the UK: $p < .001$). For the Japanese data, post-hoc comparisons revealed significant differences in smell [*adj.p* < .001, odds ratio (OR) = 0], touch (*adj.p* < .001, OR = 1.97), taste (*adj.p* < .001, OR = 0.03), and vision (*adj.p* < .001, OR = 4.56) but not in audition (*adj.p* = .499, OR = Inf). Japanese participants were more likely to spontaneously associate shapes with visual and touch descriptors for geometry (vs. food), while they were more likely to spontaneously generate smell and taste descriptors for food (vs. geometry). For the UK data, post-hoc comparisons revealed significant differences in audition (*adj.p* < .001, OR = 6.15), touch (*adj.p* < .001, OR = 0.13), taste, (*adj.p* < .001, OR = 0.02), and vision (*adj.p* < .001, OR = 2.37) but not in smell (*adj.p* = 1.00, OR = 0.57). British participants were more likely to spontaneously associate shapes with visual and auditory descriptors for geometry (vs. food products), while they were more likely to spontaneously generate touch and taste descriptors for food (vs. geometry).

Food versus Non-food

The results demonstrated significant differences in the proportions of sensory descriptors between geometric shapes and food products (Japan: $p < .001$; UK: $p < .001$). For the Japanese data, post-hoc comparisons showed significant differences in touch (*adj.p* < .001, OR = 0.47), taste (*adj.p* < .001, OR = 151.00), smell (*adj.p* = .003, OR = Inf), and vision (*adj.p* < .001, OR = 0.22) but not in audition (*adj.p* = .431, OR = 0). Japanese participants were more likely to spontaneously associate shapes with taste and smell descriptors for food (vs. non-food), while they were more likely to spontaneously generate visual and touch descriptors for non-food (vs. food). For the UK data, post-hoc comparisons showed significant differences in touch (*adj.p* = .006, OR = 2.52), taste (*adj.p* < .001, OR = 106.00), and vision (*adj.p* < .001, OR = 0.14) but not in audition (*adj.p* = .746, OR = 0.76) and smell (*adj.p* = 1.00, OR = 1.58). British participants were more likely to spontaneously associate shapes with touch and taste descriptors for food (vs. non-food), while they were more likely to spontaneously generate visual descriptors for non-food (vs. food).

Geometry versus Non-food

The results demonstrated significant differences in the proportions of sensory descriptors between geometric shapes and non-food products for British participants ($p < .001$) but not for Japanese participants ($p = .240$). For the UK data, post-hoc comparisons revealed significant differences in audition (*adj.p* < .001, OR = 4.69), touch (*adj.p* = .047, OR = 0.32), and vision (*adj.p* < .001, OR = 0.34), but not in smell (*adj.p* = 1.00, OR = 0.90) and taste (*adj.p* = 1.00, OR = 1.80). British participants were more likely to spontaneously associate shapes with auditory descriptors for geometry (vs. non-food products), while they were more likely to spontaneously generate visual and touch descriptors for non-food products (vs. geometry).

Results of Cross-cultural Differences in Spontaneous Sensory Associations

We investigated cultural differences in spontaneous sensory descriptors in terms of geometric shapes, food, and non-food products. These methods are similar to those explained above.

Geometry Shapes

In the geometry shape conditions, the results revealed a significant difference between Japan and the UK ($p < .001$). Pairwise comparisons showed significant differences in audition (*adj.p* < .001, OR = 0.01) and touch (*adj.p* < .001, OR = 18.2) but not in vision (*adj.p* = .073, OR = 1.49), smell (*adj.p* = .484, OR = 0), and taste (*adj.p* = .484, OR = 2.63). This means that Japanese (vs. British) participants were more likely to spontaneously associate geometric shapes with touch descriptors, while British (vs. Japanese) participants were more likely to spontaneously associate geometric shapes with auditory descriptors.

Food Products

In the food product conditions, the results revealed a significant difference between Japan and the UK ($p < .001$). The pairwise comparisons showed significant differences in audition (*adj.p* < .001, OR = 0) and taste (*adj.p* = .015, OR = 1.64) but not in vision (*adj.p* = .465, OR = 0.78), smell (*adj.p* = .465, OR = 3.36), and touch (*adj.p* = 483, OR = 1.64). Specifically, Japanese (vs. British) participants were more likely to spontaneously associate shapes on food products with taste descriptors, while

British (vs. Japanese) participants were more likely to spontaneously associate shapes on food products with auditory descriptors.

Non-food Products

In the non-food product conditions, the results revealed a significant difference between Japan and the UK ($p < .001$). The pairwise comparisons showed significant differences in audition (*adj.p* < .001, OR = 0.02), touch (*adj.p* < .001, OR = 6.23), and vision (*adj.p* <. 001, OR = 0.51). but not in smell (*adj.p* = .728, OR = 0) and taste (*adj.p* = 1.00, OR = 1.15). Specifically, Japanese (vs. British) participants were more likely to spontaneously associate shapes on non-food products with touch and visual descriptors, while British (vs. Japanese) participants were more likely to spontaneously associate non-food products with auditory descriptors.

Results of Spontaneous Sensory Associations in Round and Angular Shapes

Round

To determine how individuals spontaneously associate round shapes with senses, a chi-squared test was conducted. For the analyses, data for each condition (geometry, food, and non-food) were collapsed. The sensory associations for Japan ($\chi 2_4 = 593.87$, $p < .001$, *Cramer's V* = 0.487) and the UK ($\chi 2_4 = 231.03$, $p < .001$, *Cramer's*

V = 0.439) were not uniformly distributed. For Japanese data, the analysis of standardized residuals revealed that vision (SR = 8.10, *adj.p* < .001) and touch (SR = 19.20, *adj.p* < .001) were overrepresented, while audition (SR = -12.50, *adj.p* < .001), smell (SR = -12.00, *adj.p* < .001), and taste (SR = -2.80, *adj.p* = .005) were underrepresented. For British data, the analysis of standardized residuals revealed that vision (SR = 14.29, *adj.p* < .001) was overrepresented, while smell (SR = -8.08, *adj.p* < .001), touch (SR = -3.18, *adj.p* < .001), and taste (SR = -3.03, *adj.p* <.001) were underrepresented. No significant difference was found in audition (SR = 0.00, *adj.p* = 1.000).

Angular

To determine how people spontaneously associate angular shapes with senses, a chi-squared test was conducted. For the analyses, the data for each condition (geometry, food, and non-food) were collapsed. The sensory associations for Japan ($\chi2_4$ = 798.42, p < .001, *Cramer's V* = 0.614) and the UK ($\chi2_4$ = 213.7, p < .001, *Cramer's V* = 0.416) were not uniformly distributed. For Japanese data, the analysis of standardized residuals revealed that vision (SR = 26.71, *adj.p* < .001) was overrepresented, while audition (SR = -11.19, *adj.p* < .001), smell (SR = -10.75, *adj.p* < .001), and touch (SR = -6.41, *adj.p* < .001) were underrepresented. No significant difference was found in taste (SR = 1.63, *adj.p* = .103). For British data, the analysis of standardized residuals revealed that vision (SR = 12.54, *adj.p* < .001) and audition (SR = 2.73, *adj.p* = .006) were overrepresented, while smell (SR = -8.79, *adj.p* < .001) and touch (SR = -4.66, *adj.p* < .001) were underrepresented. No significant difference was found in taste (SR = -1.82, *adj.p* = .069).

Results of Contextual Differences in Spontaneous Sensory Associations in Combined Sample (Japanese and British participants)

Geometry versus Food

To determine whether the proportions of selection for sensory descriptors could differ between geometric shapes and food products, Fisher's exact test for count data was conducted. The results of Fisher's exact test demonstrated significant differences in the proportions of sensory descriptors between geometric shapes and food products (*p* < .001). The results of post-hoc pairwise comparisons with the Holm procedure showed significant differences in audition (*adj.p* < .001, OR = 4.02), smell (*adj.p* = .002, OR = 0.07), tastes (*adj.p* < .001, OR = 0.03), and vision (*adj.p* < .001, OR = 3.64) but not in touch (*adj.p* = .097, OR = 1.25). This means that participants were more likely to spontaneously associate shapes with visual and auditory descriptors for geometry (vs.

food products), while they were more likely to spontaneously associate shapes with olfactory and taste descriptors for food products (vs. geometry).

Food versus Non-food

To determine whether the proportions of selection for sensory descriptors could differ between food and non-food products, Fisher's exact test for count data was conducted. The results of Fisher's exact test demonstrated significant differences in the proportions of sensory descriptors between food and non-food products ($p < .001$). The results of post-hoc pairwise comparisons with the Holm procedure showed significant differences in touch ($adj.p < .001$, OR = 0.53), taste ($adj.p < .001$, OR = 15.10), and vision ($adj.p < .001$, OR = 0.35) but not in smell ($adj.p = .059$, OR = 0.46) and audition ($adj.p = .538$, OR = 0.82). The results indicated that participants were more likely to spontaneously associate shapes with touch, taste, and smell descriptors for food (vs. non-food), while they were more likely to spontaneously associate shapes with visual descriptors for non-food (vs. food).

Geometry versus Non-food

To determine whether the proportions of selection for sensory descriptors could differ between geometric and non-food products, Fisher's exact test for count data was conducted. The results of Fisher's exact test demonstrated significant differences in the proportions of sensory descriptors between geometric shapes and non-food products ($p < .001$). The results of post-hoc pairwise comparisons with the Holm procedure showed significant differences in vision ($adj.p = .047$, OR = 1.29), audition ($adj.p < .001$, OR = 3.30), smell ($adj.p < .001$, OR = 0.03), touch ($adj.p = .012$, OR = 0.67), and taste ($adj.p = .023$, OR = 0.39). This means that participants were more likely to spontaneously associate shapes with visual and auditory descriptors for geometry (vs. non-food products), while they were more likely to spontaneously associate shapes with touch, taste, and smell descriptors for non-food products (vs. geometry).

Discussion

We studied how individuals spontaneously associate shapes with information from different senses and how contexts modulate these associations. Consistent with the theory of situated conceptualization, the results demonstrate that spontaneous sensory associations are grounded in contexts (background situations, culture). Visual and auditory descriptors are more frequently used for geometry (vs. food products), whereas chemosensory (smell and taste) descriptors are more predominantly used for food products (vs. geometry). For cultural differences, Japanese (vs. British) participants were more likely to spontaneously associate geometric shapes with touch descriptors and associated shapes on food packaging with taste descriptors. In contrast, British (vs. Japanese) participants were more likely to spontaneously associate geometric shapes and shapes on food packaging with auditory and visual descriptors. Our results suggest that contexts act as top-down influences on the spontaneous associations between shape curvature and other senses.

Previous studies have shown that different contexts (e.g., surrounding products and culture) influence the extent to which individuals associate different senses across modalities (Motoki & Velasco, 2021; Wan et al., 2014). In line with this evidence, our results demonstrated that spontaneous sensory associations are dependent on contexts. In the context of geometric shapes, British and Japanese participants tend to associate shapes with auditory descriptors and touch-related words, respectively. In the context of food products, participants spontaneously generated taste-related words after seeing the shape features. In the context of non-food products, participants, specifically Japanese, tend to associate shape features with touch-related words. Together, these findings suggest that individuals can spontaneously generate crossmodal correspondences depending on the contexts.

In terms of cultural differences, Japanese participants tended to associate shape features with touch-related words, regardless of the context. This tendency was not observed in British participants who rarely used touch-related words to describe shape features. Instead, British participants tended to use auditory words to associate with shape features. Cultural differences might be derived from sensory dominance in each language. English words (verbs) are overrepresented in the sounds (and vision) among sensory domains, while touch, smell, and taste words are underrepresented (Lynott et al., 2020; Strik, Lievers, & Winter, 2018). In contrast, in Japan, touch-related words are predominantly represented in the form of ideophones (Uchida et al., 2021). Taken together, our findings suggest cultural differences in spontaneous crossmodal correspondences and sensory dominance when each language may shape the differences.

There are some limitations in our study. First, the stimulus was a black colored, though the black color was consistent across conditions. The color might influence our findings, and the other color (e.g., pink) might lead to the different findings. This is worth considering in future studies. Second, our findings are obtained by only shape stimuli. Further studies need to confirm the generalizability of our findings by employing other sensory stimuli. Third, to some extent, our results contradict the proxemics literature (Hall, 1966; Otterbring et al., 2021). In the literature, Japan is considered a low-contact culture. Individuals from these cultures value considerable interpersonal distances and avoid personal touch (at least with strangers) to a greater extent than those from high-contact cultures (e.g., Latin America; Hall, 1966; Otterbring et al., 2021). The explanation from proxemics literature may apply to social cues (e.g., advertising model) but not to non-social cues such as those in our study (e.g., T-shirt). Further research should test spontaneous associations in different cultures using social and non-social cues.

Our findings demonstrate that context influences spontaneous associations of shape features with different senses. Therefore, research on crossmodal correspondences may need to examine top-down effects on spontaneous associations.

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Table 1

Frequency of Spontaneous Sensory Associations in Japan and the UK

		Vision		Audition		Smell		Touch		Taste		Total	
JAPAN	Round	206	32.96%	0	0.00%	5	0.80%	317	50.72%	97	15.52%	625	100%
	Angular	352	66.42%	3	0.57%	7	1.32%	47	8.87%	121	22.83%	530	100%
	Total	558	48.31%	3	0.26%	12	1.04%	364	31.52%	218	18.87%	1155	100%
UK	Round	159	53.00%	60	20.00%	4	1.33%	38	12.67%	39	13.00%	300	100%
	Angular	150	48.54%	81	26.21%	0	0.00%	29	9.39%	49	15.86%	309	100%
	Total	309	50.74%	141	23.15%	4	0.66%	67	11.00%	88	14.45%	609	100%

Table 2

Frequency of Spontaneous sensory associations as a Function of Conditions (Geometry, Food, and Non-food) and countries (Japan and the UK)

		Vision		Auditory		Smell		Haptics		Taste		Total	
JAPAN													
Geometry	Round	89	37.71%	0	0.00%	0	0.00%	141	59.75%	6	2.54%	236	100%
	Angular	171	90.00%	2	1.05%	0	0.00%	12	6.32%	5	2.63%	190	100%
	Total	260	61.03%	2	0.47%	0	0.00%	153	35.92%	11	2.58%	426	100%
Food	Round	51	23.29%	0	0.00%	5	2.28%	72	32.88%	91	41.55%	219	100%
	Angular	55	28.06%	0	0.00%	7	3.57%	20	10.20%	114	58.16%	196	100%
	Total	106	25.54%	0	0.00%	12	2.89%	92	22.17%	205	49.40%	415	100%
Non-food	Round	66	38.82%	0	0.00%	0	0.00%	104	61.18%	0	0.00%	170	100%
	Angular	126	87.50%	1	0.69%	0	0.00%	15	10.42%	2	1.39%	144	100%
	Total	192	61.15%	1	0.32%	0	0.00%	119	37.90%	2	0.64%	314	100%
The UK													
Geometry	Round	50	48.54%	46	44.66%	1	0.97%	4	3.88%	2	1.94%	103	100%
	Angular	53	54.08%	43	43.88%	0	0.00%	2	2.04%	0	0.00%	98	100%
	Total	103	51.24%	89	44.28%	1	0.50%	6	2.99%	2	1.00%	201	100%
Food	Round	35	33.02%	12	11.32%	2	1.89%	21	19.81%	36	33.96%	106	100%
	Angular	35	26.69%	14	11.48%	0	0.00%	24	19.67%	49	40.16%	122	100%
	Total	70	30.70%	26	11.40%	2	0.88%	45	19.74%	85	37.28%	228	100%
Non-food	Round	74	81.32%	2	2.20%	1	1.10%	13	14.29%	1	1.10%	91	100%
	Angular	62	69.66%	24	26.97%	0	0.00%	3	3.37%	0	0.00%	89	100%
	Total	136	75.56%	26	14.44%	1	0.56%	16	8.89%	1	0.56%	180	100%

Figure 1

Stimuli used in the experiment

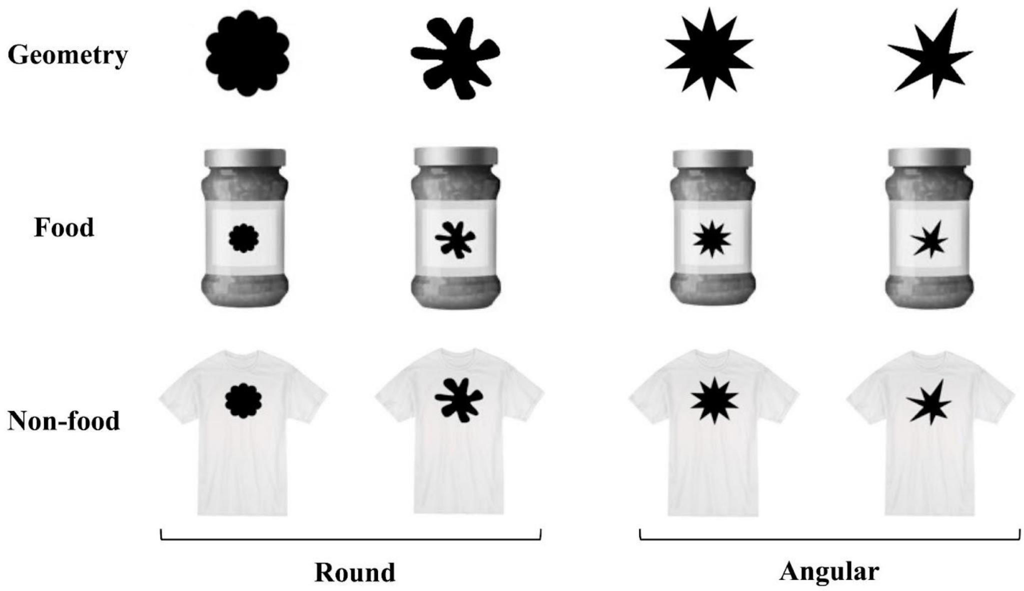
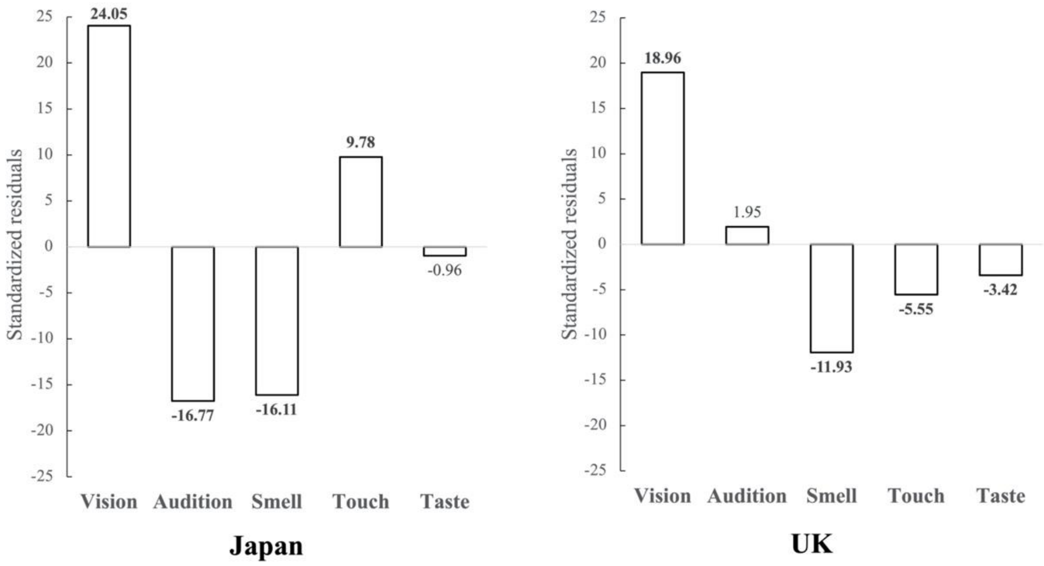


Figure 2

Results of the analysis of standardized residuals



Appendix A
Frequently Mentioned Words in Each Context

The following are the top 10 frequently mentioned words in each context:

Geometric Shapes in Japan

- Round shapes: yawarakai(39), fuwafuwa(23), mokomoko(14), mokumoku (10), marui(9), mohumohu(9), kunyakunya(8), kurai(8), bechatto(8), nebaneba(8)
- Angular shapes: togetoge(44), surudoi(22), gizagiza(15), togetogeshii(10), togatteiru(9), chikuchiku(8), kirakira(6), kurai(5), kagayaku(5), tuntun(4)

Food Products in Japan

- Round shapes: amai(38), yawarakai(14), kurai(10), maroyaka(9), tsurai(8), fuwafuwa(8), nigai(7), marui(6), katai(6), suppai(5)
- Angular shapes: karai(60), suppai(14), kurai(9), nigai(9), akai(8), gekikara(8), siokarai(6), chikuchiku(5), togetoge(4), tuntun(4)

Non-food Products in Japan

- Round shapes: fuwafuwa(24), yawarakai(18), mokomoko(11), kurai(10), gunyagunya(9), marui(7), kuroi(6), mokumoku(5), shiroi(5), dorodoro(3)

- Angular shapes: togetoge(29), togatteiru(9), akarui(9), gizagiza(8), kuroi(7), surudoi(7), shiroi(5), igaiga(5), hukisoku(4), kurai(3)

Geometric Shapes in the UK

- Round shapes: splat (42), black (34), dark (10), soft (4), quiet (3), colorful (2), sweet (2), pink (2)
- Angular shapes: bang (33), black (23), dark (13), bright (8), loud (4), yellow (3), exclamation (2), colorful (2)

Food Products in the UK

- Round shapes: grey (22), splat (12), sweet (12), soft (11), taste (9), dark (5), black (5), tasteless (3), tangent (3), cold (2)
- Angular shapes: grey (20), spicy (18), bang (13), sharp (11), hot (7), dark (5), taste (5), sweet (4), flavor (3), salt (3)

Non-food Products in the UK

- Round shapes: white (35), black (23), dark (9), soft (5), monochrome (5), splat (2), ky (2), cool (2)

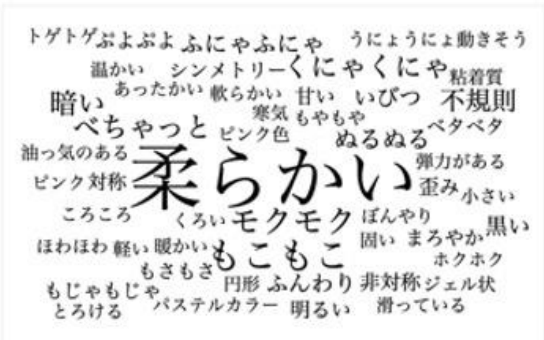
- Angular shapes: white (23), bang (21), black (16), bright (7), yellow (3), spark (3), lightening (3), splat (2), monochrome (2)

Appendix B

Visual Illustrations of Spontaneous Sensory Associations Using WordCloud

(https://worditout.com/word-cloud/create)

Geometric Shapes in Japan



Note: The left figure indicates the words derived from round shapes. The figure on the right denotes words derived from angular shapes.

Food Products in Japan

Note: The left figure indicates the words derived from round shapes. The figure on the right denotes words derived from angular shapes.

Non-food Products in Japan

Note: The left figure indicates the words derived from round shapes. The figure on the right denotes words derived from angular shapes.

Geometric Shapes in the UK

Note: The left figure indicates the words derived from round shapes. The figure on the right denotes words derived from angular shapes.

Food Products in the UK

Note: The left figure indicates the words derived from round shapes. The figure on the right denotes words derived from angular shapes.

Non-food Products in the UK

Note: The left figure indicates the words derived from round shapes. The figure on the right denotes words derived from angular shapes.