Altering Taste Judgments with Shapes: How and When Shape–Taste Crossmodal Correspondences Can Be Applied in Marketing Designs

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Abstract

Crossmodal sensory correspondences between shape and taste are well-established (e.g., angular–bitter, rounded–sweet). However, the extent to which these correspondences reliably influence consumer taste judgments is less clear, as are the processes underlying the effects. This research addresses both issues. Across seven experiments, we show that whether shape–taste correspondences influence taste judgments depends on their associative strength in memory, and that a significant shape–taste correspondence spontaneously affects taste judgments only when its associative strength reaches a sufficient threshold. We further demonstrate the effects in a child development context, in which children's age, as a naturally occurring proxy of associative strength, moderates shape–taste crossmodal effects on taste judgments. We also demonstrate that the generation of shape–taste crossmodal effects is driven by a simple spreading activation model that is moderated by associative strength, is highly automatic, and occurs even when cognitive and visual resources are constrained. The findings suggest that 1) managers must go beyond establishing simple crossmodal correspondences to determine whether sufficient thresholds are met, 2) the shape–taste associations can apply to products marketed to older children, and 3) the effects are likely to occur even in cognitively noisy retail environments.

Keywords: crossmodal correspondence, sensory marketing, product designs, food marketing, shape symbolism

When consumers make choices about which foods or drinks to buy, they rely on their existing taste preferences, and these preferences vary across consumers: some like their nuts salty, their chocolate bitter, or their bottled water carbonated. However, when choosing a food or a drink for the first time, it is difficult, if not impossible, for consumers to know what the food tastes like before purchase. Although product manufacturers may provide some explicit information that conveys the taste of the product, this information may provide little help to non-connoisseurs (e.g., interpreting water carbonation in terms of mg/l or pH, chocolate bitterness in terms of percent cocoa, or saltiness in terms of milligrams of sodium).

In such situations, how do consumers decide which product is most likely to meet their taste needs? Research on crossmodal sensory correspondences (matches between features in one sensory modality and features in another sensory modality; Krishna 2012) suggests that consumers may rely on subtle shape cues, such as the shape of a product's logo or the shape of the product itself, that signal to them the likelihood of a specific taste. In fact, previous research has documented reliable shape–taste crossmodal correspondences in which certain shapes (e.g., angular, rounded) are matched with certain tastes (e.g., bitterness, sweetness), and research has also shown that certain crossmodal correspondences can influence taste judgments (for a review, see Krishna, Cian, and Aydınoğlu 2017).

Given the prior research just noted, it may be tempting to conclude that marketers can directly apply established shape–taste correspondences to their design of products or logos, providing them with a convenient and inexpensive method for signaling their products' taste attributes. This issue is extremely important for marketers: sending accurate taste-related signals to consumers should increase brand satisfaction, and avoid dissatisfaction when expectations are not met through inaccurate signals (Krishna et al. 2017). However, as we discuss in more detail presently, even though certain shape–taste correspondences appear to be highly reliable, the extent to which these correspondences influence taste judgments is much less clear, with highly inconsistent findings that are difficult to interpret.

In the present research, we propose that the mere establishment of shape–taste crossmodal correspondences is a necessary, but not sufficient, condition for realizing shape–taste crossmodal effects on taste judgments. Rather, we propose that whether shape–taste correspondences produce effects on taste judgments is a function of the underlying processes of crossmodal effects. More specifically, we propose that whether crossmodal correspondences between shape and taste produce effects on taste judgments is a function of the strength of association in memory between the two sensory features, and that the associative strength in memory must reach a certain threshold to influence taste judgments.

We also test boundary conditions that are both theoretically and managerially relevant. In particular, we propose that, because shape–taste correspondences are likely learned from environmental cues (associations) over time, then both shape–taste correspondences and their applications to taste judgments should follow a child developmental process, and thus be stronger for older children than for younger children. This possibility has implications for marketing to children. In addition, we also test the extent to which the effects are relatively automatic, or whether they depend on either cognitive resources or mental imagery resources, which have implications for whether the effects obtain in highly distracting online and offline shopping environments.

Our research makes several contributions. First, we illuminate the processes that drive the effects of crossmodal sensory correspondences on taste judgments. Previous research has primarily focused on the establishment of crossmodal effects at the phenomenon level, with comparatively little attention to the operating mechanisms. Second, our focus on the underlying process is not merely for theory development. Understanding these underlying processes have direct managerial applications, and suggest managerially relevant boundary conditions and implications for the conditions under which the effects should be observed. Thus, our research makes clear contributions to both theory and practice.

Shape–Taste Crossmodal Effects[1]

Research shows that individuals can reliably match shapes and tastes. For example, angular shapes are matched with bitter, sharp, sour, and carbonated tastes, and rounded shapes are matched with sweet, mild, and smooth tastes (Ngo, Misra, and Spence 2011; Spence et al. 2013; Spence and Gallace 2011). However, the findings about whether the shape–taste crossmodal correspondences influence taste judgments are mixed. For example, in one study, participants expected that beverages in angular-shaped bottles would taste more sour and less sweet than beverages in rounded-shaped bottles (Velasco et al. 2014). In contrast, in another study, participants thought foods served on round plates tasted sweeter than those same foods served on angular (square) plates, but plate shape did not affect their perceptions of sourness

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[1] Here and throughout, we refer to associations between shape and taste as *crossmodal correspondences*, and the application of these correspondences to taste judgments as *crossmodal effects*.

(Fairhurst et al. 2015). Still other studies find no effects of shape (angular vs. rounded) on participants' perceptions of sweetness (Piqueras-Fiszma et al. 2012; Stewart and Goss 2013). Similar inconsistent findings on shape–taste crossmodal effects have been reported for other tastes, such as sharpness (Gal, Wheeler, and Shiv 2007; Harrar and Spence 2013) and taste intensity (Becker et al. 2011; Piqueras-Fiszma et al. 2012; Stewart and Goss 2013). In short, although individuals can reliably match shapes to tastes (that is, shape–taste crossmodal correspondences reliably exist), the crossmodal effects of shapes on taste judgments are *not* consistently observed. The relatively low robustness of the shape–taste crossmodal effects seriously limits their applications in marketing designs to influence consumers' taste expectations and experiences.

Although it is difficult to generalize across a small number of studies that differ on many characteristics, as we discuss in the following sections, shape–taste correspondences are likely learned associations. If so, the strengths of these associations may vary across learning environments and may even vary in the course of individual development. Consequently, we propose that even though shape–taste associations may exist for particular consumers, the associations may not be sufficiently strong to produce effects on taste judgments. Thus, the existence of shape–taste associations may be a necessary, but not sufficient, condition for producing effects on taste judgments.

Underlying Mechanisms of Shape–Taste Crossmodal Effects

Spreading Activation and Associative Strength

We conceptualize crossmodal sensory correspondences in terms of a spreading-activation theory of semantic processing (Collins and Loftus 1975). Spreading-activation theory regards human memory as a semantic associative network in which concepts and knowledge are stored in the form of nodes. Associations are represented by connections between the nodes (e.g., the nodes of shapes and tastes), and the length of the connections between nodes (concepts) reflects the strength of their association: the shorter the linkage between nodes, the stronger the association between them. Thus, in terms of shape–taste correspondences, when a shape node is activated via being exposed to a shape stimulus (e.g., angular shape), it will automatically spread out to and activate the connected nodes of tastes (e.g., carbonation, bitterness), which in turn increases the accessibility of the taste nodes. However, a simple linkage between nodes does not guarantee that activation of one node will activate another linked node. Rather, for the association (link) to be activated, the associative strength must reach a sufficient activation threshold (Collins and Loftus 1975). This is an important issue for marketing. If exposure to a shape (e.g., via logo, packaging, product) does not spontaneously activate the related taste dimension, then shape will have no effects on consumer judgments in natural (e.g., in-store) settings.

The issue of associative strength thresholds also has important implications for whether the crossmodal association will affect taste judgements. For these associations to impact taste judgments, we argue that the crossmodal association must be sufficiently strong such that it is not only activated, but also spontaneously applied to the judgment. In other words, we argue that the associative strength must reach a sufficient threshold for automatic application to taste judgments. We refer to this threshold as the *application threshold*. Moreover, the application threshold must necessarily be greater than the minimum activation threshold. We test these propositions in our studies. If our reasoning is correct, it may potentially explain why some studies on known shape–taste correspondences do not always produce downstream effects on taste judgments.

Associative Strength and Developmental Differences

Shape–taste crossmodal correspondences vary across cultures. For example, in contrast to the shape–taste crossmodal correspondences widely accepted in western cultures, the Himba (an ethnic group in northern Namibia) do not map carbonation onto angular shapes, and they tend to match sweetness to angular shapes rather than rounded shapes (Bremner et al. 2013). Although cross-cultural differences are not the focus of the present research, they do suggest that the perceptual associations are likely learned from environmental cues, rather than reflecting innate associations (cf. Henrich, Heine, and Norenzayan 2010; Spence and Deroy 2012). If so, then the strength of the associations should increase over time during the child developmental process.

Indeed, there is a close relationship between the development of semantic associations and abstract reasoning ability (Hutchison 2003). Building on Piaget's (1964) theory of cognitive development, John (1999) suggests that children in the perceptual stage (around ages 3-7) focus predominantly on perceptual features of stimuli, typically a single dimension, but lack abstract reasoning that connects multiple features. However, as children move into the analytical stage (around ages 7-11), their thinking shifts from a perceptual orientation to a more abstract orientation, which enables them to consider abstract, common features of objects and events, and thus develop corresponding semantic associations. Thus, we propose that children are more likely to develop shape–taste crossmodal correspondences at the analytical stage. In addition, these associative strengths should increase as children age, to the point that they reach the application threshold, and thus the effects of shape–taste correspondences on taste judgments are also likely to start occurring at this stage. If so, crossmodal effects on taste judgments are more likely to occur among adults and older children than among younger children.

Automaticity of Shape–Taste Crossmodal Effects

Extant research on the operating mechanism underlying the effects of shape–taste correspondence on taste judgments is unclear. For example, consistent with the spreading activation model, some research suggests that the application of crossmodal correspondences is highly automatic, occurring even when cognitive processing resources are constrained (e.g., Hagtvedt and Brasel 2016; Yorkston and Menon 2004). However, other research suggests that the process may be a more strategic one that requires visualization resources, which is regarded as an additional and necessary psychological stage (e.g., Jiang et al. 2016; Lowe and Haws 2017). The research by Jiang et al. (2016) is particularly relevant because it also involves the influence of shape symbolism on judgments. For example, in one study, the shape of a logo (angular, rounded) influenced perceptions of comfort and durability of a sofa (Jiang et al. 2016). However, these effects were eliminated under visual load conditions that inhibit visuospatial working memory, and the effects were observed only for those scoring higher on an imagery disposition measure. They explain the necessity of mental imagery by arguing that when consumers encounter product pictures or verbal descriptions of a product, they will spontaneously generate a mental image of the product's attributes, which plays an important role in judgments of a product's sensory attributes.

In contrast, we propose that whether a crossmodal effect requires mental imagery processes depends on how individuals typically construct sensory judgments for product's attributes. Specifically, whether a crossmodal effect requires a mental imagery process is likely to be contingent on whether individuals spontaneously generate mental images of the target when they make judgments about its sensory qualities, such as whether a sofa will be comfortable or durable (Jiang et al. 2016). In fact, mental imagery is usually involved when making perceptual judgments of haptic features (James et al. 2002), consistent with the findings of Jiang et al. (2016). In such cases, if the mental imagery process is inhibited, then the application of the accessible crossmodal associations may also be inhibited.

However, not all sensory judgments require mental imagery. A typical example is taste judgments. Mental imagery is not a necessary component for taste judgments (Kobayashi et al. 2004), and thus it is unlikely that individuals would spontaneously generate images to judge how a product should taste. In such cases, the accessible crossmodal association of shape and taste should be successfully applied to taste judgments even if visual processing abilities are constrained. Our research tests these possibilities, in particular whether the effects of shape–taste correspondence on taste judgments are driven by a simple spreading activation model that is moderated by associative strength, or by a more complex model that requires mental imagery, and if the necessity of mental imagery is contingent on individuals' styles for constructing sensory (taste) judgments.

[Insert Figure 1 about here]

Empirical Overview

Figure 1 illustrates our conceptual framework. The primary hypothesis we test is that the effect of shape–taste correspondences on taste perceptions is moderated by associative strength of the correspondences: the effects occur only when the associative strength of the correspondence reaches a sufficient application threshold. We test this hypothesis in the context of shape effects (rounded vs. angular) on two different taste judgments (bitter–sweet, using chocolate bars, and carbonated–smooth, using bottled waters). We manipulated shape through either the logo (bottled water) or the product shape (chocolate bar). We also test whether the effects are highly automatic, or require visualization resources. For the bottled water studies in particular, we conducted the studies with participants from a country (France) in which bottled water is a highly differentiated product category, and personal tastes exhibit clear variation in terms of preferences for sparkling and still waters and degrees of carbonation and smoothness.

Studies 1a-1c examine the critical role of associative strength of shape–taste crossmodal correspondences in the generation of shape–taste crossmodal effects. Studies 1a and 1b directly test the moderating role of associative strength. Study 1c further explores the role of associative strength and automatic activation. Study 2 tests our developmental hypothesis that children's age, as a naturally occurring proxy of associative strength, moderates the effects of shape–taste correspondences on taste perceptions. Studies 3a and 3c further explore the underlying mechanism of shape–taste crossmodal effects by examining whether they are cognitive- or visual-load-dependent and whether visual training can shape the effects.

Table 1 provides an overview of these studies. Across all studies, we analyzed the data only after all responses had been collected. No participants' data are excluded from analyses, and details of all measures and manipulations are provided in the Web Appendix. The raw data are also anonymously posted and publicly available at https://osf.io/f5rgs/?view_only=3bad633378a244ac936e8349db11645b

Study 1a

Study 1a tested whether shape–taste crossmodal correspondences influence taste judgments, and more importantly, whether the generation of the shape–taste crossmodal effects depends on the associative strengths of the shape–taste crossmodal correspondences. We manipulated the product shape of a chocolate bar and compared participants' judgments of how bitter and sweet the chocolate bar would taste between angular and rounded product shapes. We also measured associative strengths of the angular-bitter and rounded-sweet correspondences and tested whether the shape–taste crossmodal effects occur only if the associative strengths reach a sufficient threshold (application threshold).

Method

Participants and design. One hundred UK-based participants (50 women; M_{age} = 39.50 years) who were recruited from the Prolific online panel were randomly assigned to conditions in a 2 (product shape: angular, rounded) × 2 (taste judgment: bitter, sweet) mixed design, with product shape as a between-subjects factor and taste judgment as a within-subjects factor.

Procedure. In a study ostensibly about consumer reactions to a product, participants were asked to carefully review either an angular chocolate bar or a rounded chocolate bar (see Web Appendix A), and then rate how sweet and bitter they thought the chocolate bar would taste (1 = not at all, 9 = very much). Next, participants indicated their attitudes toward the product shapes (how much they liked them) along a 3-item, 9-point scale (1 = not at all, 9 = very; α = .92). Finally, participants were shown a series of slider line scales, anchored by angular or rounded shape at the left (-4) or right end (4), which have been widely used in previous research (e.g., Velasco et al. 2016; Web Appendix A). (The numbers represent distance from the mid-point of the line).

The scale items consisted of four visual scale items anchored with different angular and rounded shapes, and one semantic scale item anchored with the words angular and rounded (see Web Appendix A). Participants were asked to drag the slider along the scale to a point that best matched bitterness or sweetness. Order of the items was counterbalanced. Composite measures of the mappings between shapes and tastes were computed by averaging the scores on the five scale items. Associative strength was operationalized as the distance from the mid-point.

Results and Discussion

Participants' attitudes toward the product shapes did not differ between the angular and rounded conditions ($M_{angular}$ = 5.45, *SD* = 1.61, $M_{rounded}$ = 5.64, *SD* = 1.87, *t*(98) = -.55, *p* = .58), ruling out the possibility that participants' taste judgments were shaped by their attitudes toward product shapes.

Associative strengths of shape–taste crossmodal correspondences. Separate one-sample *t*-tests with 0 (the mid-point of the shape scale) as the test value showed that the crossmodal correspondences between angular shape and bitterness (*M* = -2.36, *SD* = 1.35, *t*(99) = -17.42, *p* < .001), and between rounded shape and sweetness (*M* = 2.36, *SD* = 1.34, *t*(99) = 17.54, *p* < .001), were both significant. A paired-samples *t*-test indicated that the absolute magnitudes of these crossmodal correspondences did not differ (*t*(99) = .001, *p* = .99), indicating similar associative strengths at an aggregate level.

Shape–taste crossmodal effects. A 2 × 2 mixed-model ANOVA, with product shape as a between-subjects factor and taste judgment as a within-subjects factor, showed that the main effect of taste judgment was significant (*F*(1, 98) = 1055.32, *p* < .001), which was qualified by a significant product shape × taste judgment interaction (*F*(1, 98) = 8.11, *p* = .005). Participants rated the chocolate bar as more bitter in the angular shape condition ($M_{angular}$ = 1.94, *SD* = .94) than in the rounded shape condition ($M_{rounded}$ = 1.54, *SD* = .76, *F*(1, 98) = 5.50, *p* = .02), and rated the chocolate bar as sweeter in the rounded shape condition ($M_{rounded}$ = 7.62, *SD* = 1.12) than in the angular shape condition ($M_{angular}$ = 7.04, *SD* = 1.25, *F*(1, 98) = 5.99, *p* = .016). These results suggest that angular shapes enhanced expectation of the chocolate's bitterness and rounded shapes enhanced expectations of the chocolate's sweetness.

Moderating effects of associative strengths on shape–taste crossmodal effects. We tested the moderating effects with Hayes' (2018) PROCESS Model 1. As expected, the interaction between product shape and associative strength between angular shape and bitterness (B = -.28, SE = .12, t = -2.29, p = .02) and between rounded shape and sweetness (B = -.37, SE = .18, t = -2.07, p = .04), were significant, indicating that the associative strengths moderate the crossmodal effects of shapes on taste judgments. Separate floodlight analyses indicate that for the angular shape–bitterness crossmodal correspondence, the Johnson-Neyman turning point (application threshold) at which the crossmodal effect becomes significant is an associative strength of -2.16, and for the rounded shape–sweetness crossmodal correspondence, the turning point is at 1.98. These results suggest that both angular–bitter and rounded–sweet crossmodal correspondences influenced individuals' taste judgments of bitterness or sweetness, but only when the associative strengths of the shape–taste crossmodal correspondences reached the application threshold (-2.16 for angular–bitter, 1.98 for rounded–sweet).

The moderation results are consistent with the results of the analyses at an aggregate level: given that participants' associative strength of angular–bitter crossmodal correspondence (at an aggregate level, M = -2.36) was past the turning point (-2.16), the angular shape enhanced the expected bitterness of the chocolate bar. Similarly, the associative strength of rounded–sweet crossmodal correspondence (at an aggregate level, M = 2.36) was above the turning point (1.98), and thus the rounded shape enhanced the expected sweetness of the chocolate bar.

The results of Study 1a show that the shape of a product influences taste expectations. More important, the results show that the associative strengths of shape–taste crossmodal correspondences moderate the crossmodal effects of shapes on taste judgments. The results also demonstrate when these associations occur, which is when the associative strengths of the shape–taste correspondences reach a sufficient application threshold for generating shape–taste crossmodal effects.

Study 1b

The objective of Study 1b was to demonstrate that the observed effects from Study 1a generalize to a different product category and different shape–taste crossmodal correspondences. We used bottled water as the product category (sparkling and still water), and shape–taste crossmodal correspondences pertain to angular shape–carbonation and rounded shape–smoothness. We manipulated the logo shape of a bottled drink (angular, rounded, no logo). The inclusion of a control group (no logo) allows us to assess the extent to which the predicted differences in the crossmodal effects between angular and rounded logos are driven by the angular shape, rounded shape, or both. Further, as with Study 1a, we again measured associative strengths of the shape–taste crossmodal correspondences.

Method

Participants and design. Two hundred forty-three French college students (144 women; M_{age} = 22.03 years) were randomly assigned to conditions in a 3 (logo shape: angular, rounded, no logo) × 2 (drink type: sparkling, still water) × 2 (taste judgment: carbonated, smooth) mixed design, with logo shape and drink type as between-subjects factors and taste judgment as a within-subjects factor.

Procedure. Participants were informed that a beverage company was launching a new bottled drink and wanted consumers' feedback on the packaging. Next, we showed participants a bottle that had either an angular or rounded logo, or no logo (as a control group), with all other package elements held constant (see Web Appendix B). Participants then rated how carbonated and how smooth they thought the drink would taste (1 = not at all, 9 = very much), and then (except for those in the control condition) indicated their attitudes toward the bottle logo along the same 3-item scale used in the previous experiment (1 = not at all, 9 = very; α = .94). Finally, the measures of associative strengths of the shape–taste correspondences were similar to Study 1a.

Results and Discussion

A 2 (logo shape) × 2 (drink type) ANOVA confirmed that there were no differences in participants' attitudes toward the logos across conditions (*p*s > .76).

Associative strengths of shape–taste crossmodal correspondences. Separate one-sample *t*-tests with 0 (the mid-point of the shape scale) as the test value showed that the crossmodal correspondences between angular shape and carbonation (M = -2.98, SD = 1.31, $t(242) = -35.39$, $p < .001$), and between rounded shape and smoothness (M = 2.07, SD = 1.92, $t(242) = 16.75$, $p < .001$), were both significant. The magnitude of angular–carbonated crossmodal correspondence ($M = 2.98$) was larger than rounded–smooth crossmodal correspondence ($M = 2.07$, $t(242) = 7.11$, $p < .001$), suggesting that the associative strength of the angular–carbonated correspondence is stronger than rounded-smooth correspondence at an aggregate level.

Shape–taste crossmodal effects. To assess the effect of crossmodal correspondence on taste judgments, we conducted separate 3 (logo shape: angular, rounded, no logo) × 2 (taste judgment: carbonated, smooth) mixed-model ANOVAs, with logo shape as a between-subjects factor and taste judgment as a within-subjects factor, for sparkling and still waters. The results of these analyses can be seen in Figure 2.[2]

For sparkling water, the main effect of taste judgment was marginally significant ($F(1, 118) = 2.96$, $p = .088$), and the interaction of logo shape and taste judgment was significant ($F(2, 118) = 9.40$, $p < .001$). As the left panel of Figure 2 shows, participants rated the sparkling water as more carbonated in the angular logo condition ($M_{angular} = 5.40$, $SD = 2.18$) than in the no logo condition ($M_{no\ logo} = 4.07$, $SD = 1.74$, $t(118) = 3.02$, $p = .003$) and in the rounded condition ($M_{rounded} = 4.28$, $SD = 2.00$, $t(118) = 2.54$, $p = .01$), with no difference between the latter two conditions ($t(118) = .46$, $p = .65$). These results suggest that the angular logo increased expectations of the sparkling water's carbonation, but the rounded logo had no effect.

For still water, the main effect of taste judgment ($F(1, 119) = 337.93$, $p < .001$) was

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[2] Our design was fully crossed, and thus participants also rated the carbonated water on smoothness and the still water on carbonation. These judgments are not relevant to our core hypotheses, and thus are not discussed here, but full details are provided in Web Appendix B.

significant, as was the interaction of logo shape and taste judgment ($F(2, 119) = 4.75$, $p = .01$). As the right panel of Figure 2 indicates, although participants rated the still water as smoother in the rounded logo condition ($M = 6.38$, $SD = 2.08$) than in the angular logo condition ($M = 5.05$, $SD = 2.09$; $t(119) = 2.86$, $p = .005$), their ratings of smoothness for still water did not differ between the rounded ($M = 6.38$, $SD = 2.08$) and no logo conditions ($M = 6.42$, $SD = 2.10$; $t(119) = .09$, $p = .93$), but ratings of smoothness decreased in the angular logo condition compared to the no logo condition ($t(119) = 2.96$, $p = .004$). These findings indicate that the rounded logo had no effect on expectations of the still water's smoothness, but that the angular logo decreased expectations of the still water's smoothness.

[Insert Figure 2 about here]

Moderating effects of associative strengths on shape–taste crossmodal effects. To specifically examine whether the associative strengths of shape–taste crossmodal correspondences moderate the crossmodal effects on taste judgments, we conducted separate moderation analyses for sparkling and still waters using Hayes' (2018) PROCESS Model 1, with logo shape (angular or rounded logo vs. no logo) as the independent variable, taste judgment (carbonation or smoothness) as dependent variables, and associative strength (angular shape–carbonation or rounded shape–smoothness) as moderators. As expected, the interactions between logo shape and associative strength for both sparkling ($B = -.74$, $SE = .33$, $t = -2.27$, $p = .026$) and still waters ($B = .82$, $SE = .23$, $t = 3.61$, $p < .001$) were significant, indicating that the associative strengths of shape–taste crossmodal correspondences moderate the crossmodal effects of shapes on taste judgments. Separate floodlight analyses further indicate that for sparkling water (angular-carbonated correspondence), the Johnson-Neyman turning point at which the crossmodal effects becomes significant is an associative strength of -2.56, and for still water (rounded shape-smoothness crossmodal correspondence), the turning point is at 3.88. These results suggest that angular-carbonated and rounded-smooth crossmodal correspondences influence individuals' carbonation and smoothness taste judgments only when the associative strength reaches the application threshold (-2.56 for angular shape-carbonation; 3.88 for rounded shape-smoothness).

The moderation results are consistent with the results of the analyses at an aggregate level: given that participants' associative strength of angular–carbonated correspondence (at an aggregate level, M = -2.98) was past the turning point (- 2.56), the angular logo enhanced expected carbonation of the sparkling water. However, in contrast, given that participants' associative strength of rounded–smooth correspondence (M = 2.07) was far below the turning point (3.88), the rounded logo did not enhance the expected smoothness of the still water.

The results of Study 1b show that even though significant angular–carbonated and rounded–smooth crossmodal correspondences may be observed, their associative strengths are not necessarily equal, and thus they may not necessarily generate shape–taste crossmodal effects in a symmetrical manner. In fact, the associative strength of the angular–carbonated correspondence is stronger than the rounded–smooth correspondence among this sample of French participants. Moreover, the angular–carbonated correspondence successfully generates the shape–taste crossmodal effect on carbonation judgment at an aggregate level, whereas the rounded–smooth correspondence does not. Thus, shape–taste crossmodal correspondences successfully influence taste judgments at an aggregate level only when their overall associative strengths reach a sufficient application threshold.

Conceptual replication with actual taste experience. To further demonstrate the generalizability of the effects we observed in Study 1b, particularly the asymmetrical crossmodal correspondence effects, we conducted a conceptual replication with the same experimental design as Study 1b, but with a different set of logo shapes and a behavioral measure of taste (actual taste of a water; see Web Appendix B for full details and results). We had participants taste either a sparkling or still water and rate each for how smooth or carbonated they tasted, and manipulated whether the exact same waters were in a bottle with a rounded logo or an angular logo. Consistent with the findings of the main study, for the angular–carbonated correspondence, the angular logo enhanced participants' perception of how carbonated the sparkling water tasted, but for the rounded–smooth correspondence, the rounded logo had no effect on smoothness for the still water tasted.

Taken together, Study 1b not only determines the application threshold (or turning point) that the associative strength should reach for successfully generating shape–taste crossmodal effects at an *individual* level, but also provides direct evidence that if the overall associative strength of shape–taste correspondence is not above the application threshold, then the shape–taste crossmodal effect (on both taste expectations and experiences) is less likely to be generated at an *aggregate* level, even though the shape–taste crossmodal correspondence is already established in a group.

Study 1c

Study 1b provided evidence of the importance of associative strength in generating shape–taste crossmodal effects on taste judgments. To provide convergent support for the role of associative strength, the current study examines its importance in crossmodal activation of taste concepts. In Study 1b, we showed that the associative strength of angular–carbonated correspondence is stronger than rounded–smooth correspondence among French participants, and thus, angular and rounded shapes asymmetrically influence carbonation and smoothness judgments. In this study, we examine whether such angular and rounded shapes asymmetrically activate carbonation and smoothness concepts among the same participant group, and whether these activations are spontaneous. In the previous studies, we measured associative strength with a slider scale in which participants matched shape and taste concepts. However, even if these mappings show significant correspondences, it does not necessarily mean that activation of a shape automatically activates a taste concept. We test this possibility in Study 1c

To do so, we used a lexical decision task in which participants were subliminally primed with either rounded or angular shapes, and then measured how quickly participants recognized either a sparkling or still water. If the subliminal presentation of an angular or rounded shape correspondingly facilitates participants' responses to a sparkling or still water, it indicates that the carbonated or smooth taste expectation is automatically activated when people are exposed to an angular or rounded shape, and not driven by any conscious application of the relation between the shapes and the expected tastes.

The subliminal priming provides a strong test of automatic activation. As a comparison condition, we also presented the stimuli supraliminally by adjusting the perceptual level such that the primed stimulus became visible but the duration was still very short. The supraliminal comparison condition allows us to rule out the possibility that potential null findings in subliminal priming conditions are because of the lack of an overall effect. Based on the findings of Study 1b, we expect that the effects of priming angular shapes on expectations of carbonation will be stronger than the effects of priming rounded shapes on expectations of smoothness.

Method

Participants and design. Twenty-nine French college students (17 women; M_{age} = 21.72) were randomly assigned to conditions in a 2 (shape: angular, rounded) × 2 (shape–taste congruity: congruent, incongruent) × 2 (perceptual level: subliminal, supraliminal) within-subjects design.

Procedure. For the priming manipulation, we used a masked priming paradigm in which an angular or rounded shape was quickly presented and hidden between a forward and a backward mask. The task consisted of four blocks that differed in the duration of the stimulus presentation and the task purpose: 12 *ms* (subliminal presentation) in the first and third blocks and 112 *ms* (supraliminal presentation) in the second and last blocks. A stimulus presentation of 12 *ms* is generally considered to be subliminal (Greenwald, Draine, and Abrams 1996). The first two blocks were used to test the crossmodal activation of shapes on taste concepts and the last two blocks were used as manipulation checks for the subliminal and supraliminal presentation. After being exposed to a shape stimulus, participants were shown either a sparkling or a still water and asked to respond (by pressing the appropriate key) as soon as they recognized the stimulus. The response latency and the error rate of each trial were recorded. We provide full details of the procedure in Web Appendix C.

Results and Discussion

Manipulation checks and data preprocessing. If the presentation of shape stimulus was indeed subliminal, then participants should not be able to guess the shape stimulus at rates greater than chance level. One-sample *t*-tests confirmed that the subliminal presentation was successful, as correct recognition rates (block 3) were not greater than chance level (M = 51.79%, SD = 6.71%; ($t(28) = 1.44$, $p = .16$). In contrast, recognition rates in the condition of supraliminal presentation (block 4) were above 90% (M = 91.93%, SD = 7.14%; $t(28) = 31.64$, $p < .001$).

We also tested for accuracy (i.e., correctly recognizing a bottled water as sparkling or still water) across blocks 1 and 2. Accuracy rates were all over 90%, and thus the data of all the participants were included in the analyses. Following established procedures (Greenwald, McGhee, and Schwartz 1998), response latencies lower than 300 *ms* were recoded as 300 *ms*, and those greater than 3000 *ms* were recoded as 3000 *ms*. We then log-transformed the response latencies (Greenwald, McGhee, and Schwartz 1998).

Shape–taste crossmodal activations. To determine whether either subliminal or supraliminal presentation of shapes activates the corresponding taste concepts, we conducted separate 2 (congruity) × 2 (perceptual level) repeated-measures ANOVAs for angular and rounded shapes. The results of these analyses can be seen in Figure 3. For the angular shape condition (top panel of Figure 3), only the main effect of congruity was significant ($F(1, 28) = 16.74$, $p < .001$). When angular shapes were subliminally presented, participants' response latencies to sparkling water (congruent group; $M = 648.92$, $SD = 144.69$) were significantly faster than to still water (incongruent group; $M = 693.77$, $SD = 180.30$; $F(1, 28) = 13.30$, $p = .001$). The same pattern of results was also observed in supraliminal priming conditions with angular shapes: participants' response latencies to sparkling water ($M = 632.06$, $SD = 124.26$) were also significantly faster than that to still water ($M = 664.34$, $SD = 139.45$; $F(1, 28) = 5.61$, $p = .025$). These results suggest that both subliminal and supraliminal presentations of angular shapes activate carbonation concepts that can facilitate participants' responses to sparkling water.

We also conducted the same analyses for the rounded shape condition (bottom panel of Figure 3). However, no effects were significant (Fs < 1, ps > .52). These results suggest that exposure to the rounded shape fails to activate the smoothness concept that can facilitate participants' responses to still water at both subliminal and supraliminal levels.

[Insert Figure 3 about here]

The results of the current study show that for the angular–carbonated correspondence, angular shapes successfully activate the carbonation concept. In contrast, for the rounded–smooth correspondence, rounded shapes do not activate the smoothness concept. These results are fully consistent with the findings of Study 1b, which also showed asymmetrical effects for angular-carbonated and rounded-smooth correspondences. These results again confirm the critical role that associative strengths of shape–taste crossmodal correspondences play in generating shape–taste crossmodal effects. The results of Study 1c also show that the crossmodal activation of shape on taste concept can occur not only at a supraliminal level but also at a subliminal level, suggesting that the crossmodal activation is highly automatic.

Study 2

The objective of Study 2 was to test our developmental hypothesis that children's age moderates the effects of shape–taste correspondences on taste perceptions. If the crossmodal correspondences are learned, then the existence and associative strengths of the correspondences should increase as children age. More specifically, we propose that shape–taste crossmodal correspondences are unlikely to be observed for children in the perceptual stage of cognitive development (roughly, < 7 yrs.), because they have not yet developed the ability to associate abstract concepts, but are likely to be observed in children who have entered the analytical stage (> 7 yrs.), in which they have developed abstract reasoning ability. If so, then not only should this age threshold determine the presence and associative strengths of shape–taste correspondences, it should also determine whether shape–taste correspondences influence taste judgments.

Method

Participants and design. Eighty-one children were recruited from a primary school in China (43 girls, range: 6-14 years, M_{age} = 9.82 years). Sample size was dependent on how many children were in school and able to participate; all who wanted to participate did. The participants were randomly assigned to conditions in a 2 (product shape: angular, rounded) × 2 (taste judgment: bitter, sweet) mixed design, with product shape as a between-subjects factor and taste judgment as a within-subjects factor.

Procedure. Participants were asked to carefully view either an angular or a rounded chocolate bar (see Web Appendix D), then rate how sweet and bitter they thought the chocolate bar would taste (1 = not at all, 9 = very much), and indicate their attitudes toward the product shapes along the same 3-item scale used in the previous experiment ($\alpha = .78$). We measured the associative strengths of the shape–taste correspondences similar to Study 1a.

Results and Discussion

Participants' liking for the product shapes did not differ between the angular and rounded conditions ($M_{angular} = 5.84$, $SD = 2.27$, $M_{rounded} = 5.84$, $SD = 2.16$, $t(79) = -.009$, $p = .99$).

Age-related differences in shape–taste crossmodal correspondences. We first examined whether shape–taste crossmodal correspondences develop with age of the children. If shape–taste correspondences develop over time, then age of children should be positively correlated with the magnitude (or associative strength) of shape–taste crossmodal correspondences. OLS regressions showed that the correlations with age were significant for both the angular–bitter correspondence ($B = -.23$, $SE = .11$, $t = -2.23$, $p = .028$) and the rounded–sweet correspondence ($B = .37$, $SE = .08$, $t = 4.43$, $p < .001$; see Figure 4).

[Insert Figure 4 about here]

To further examine the nature of this relation, we divided the age range (6-14 years) into three segments based on the standard deviations: younger children (< 7.85 yrs., < 1 *SD*), older children (> 11.77 yrs., > 1 *SD*), and middle children (7.85–11.77 yrs.), which roughly correspond to the age ranges for John's (1999) stages of cognitive development (perceptual, analytical, reflective). We then conducted separate mixed-model ANOVAs, with age group as a between-subjects factor (younger, middle, older children) and shape–taste associative strength for angular–bitter and rounded–sweet correspondences as a within-subjects factor.

For the angular–bitter correspondence, the main effect of shape–taste associative strength ($F(1, 78) = 9.34$, $p = .003$) was significant, but the main effect of age group ($F(2, 78) = 2.09$, $p = .13$) and the interaction ($F(2, 78) = 2.09$, $p = .13$) were not. Younger children did not show a significant angular–bitter correspondence ($M = -.06$, $SD = 2.03$, $F(1, 78) = .02$ $p = .90$), whereas middle ($M = -.70$, $SD = 1.82$, $F(1, 78) = 7.18$, $p < .001$) and older children ($M = -1.43$, $SD = 1.79$, $F(1, 78) = 8.86$, $p = .004$) did.

For the rounded–sweet correspondence, the main effects of shape–taste associative strength ($F(1, 78) = 29.11$, $p < .001$), age group ($F(2, 78) = 3.92$, $p = .024$), and their interaction ($F(2, 78) = 3.92$, $p = .024$) were all significant. Simple effect analyses further showed that younger children did not develop a significant rounded–sweet correspondence ($M = .24$, $SD = 1.67$, $F(1, 78) = .39$, $p = .54$), whereas middle ($M = 1.28$, $SD = 1.65$, $F(1, 78) = 33.27$, $p < .001$) and older children ($M = 1.75$, $SD = 1.12$, $F(1, 78) = 18.58$, $p < .001$) did.

Taken together, similar patterns as a function of age were observed for both angular–bitter and rounded–sweet correspondences, but the development of the rounded–sweet correspondence and its associative strength occurred somewhat earlier and was stronger than the angular–bitter correspondence.

Age-related differences in shape–taste crossmodal effects. We next examined whether the shape–taste correspondences influenced taste judgments, and whether the shape–taste crossmodal effects were moderated by children's age, by conducting separate moderation analyses via Hayes' (2018) PROCESS Model 1, with product shape (angular vs. rounded) as the independent variable, taste judgment (bitter or sweet) as dependent variables, and age as the moderator.

For the crossmodal effect of angular shape on bitterness judgment, the product shape × age interaction was marginally significant ($B = .34$, $SE = .18$, $t = 1.87$, $p = .065$). The angular shape did not affect bitterness judgments for younger children ($B = -.07$, $SE = .50$, $t = -.15$, $p = .89$), consistent with the finding that the angular–bitter correspondence did not occur for younger children. In contrast, the crossmodal effect for the middle age group was marginally significant ($B = .59$, $SE = .35$, $t = 1.68$, $p = .097$), and the crossmodal effect for the older age group was significant ($B = 1.25$, $SE = .50$, $t = 2.52$, $p = .014$). The Johnson-Neyman technique showed that the turning point at which the angular shape affects bitterness judgments is 10.17 years of age.

For the crossmodal effect of rounded shape on sweetness judgments, the product shape × age interaction was significant ($B = -.32$, $SE = .12$, $t = -2.68$, $p = .009$). The rounded shape did not affect sweetness judgments for younger children ($B = -.17$, $SE = .33$, $t = -.51$, $p = .61$), consistent with the finding that the rounded–bitter correspondence did not occur for younger children, whereas the crossmodal effects for the middle age group (*B* = -.78, *SE* = .23, *t* = -3.42, *p* = .001) and older age group (*B* = -1.40, *SE* = .32, *t* = -4.32, *p* < .001) were significant. The Johnson-Neyman technique showed that the turning point at which the rounded shape affects sweetness judgments is 8.92 years of age.

These results suggest that shape–taste crossmodal effects influence children's taste judgments, but only for children who are at the analytical and reflective stages of cognitive development. The results also suggest that not all shape–taste crossmodal effects occur at the same age. The angular–bitter crossmodal effect occurs approximately 15 months later than the rounded–sweet crossmodal effect, which is perhaps because of the relatively late development of the angular–bitter crossmodal correspondence. The findings further bolster our theoretical reasoning, but also have implications for marketing applications for children, which we discuss in more detail presently. In the next two studies, we further investigate the processes that underlie the crossmodal effects on taste judgments.

Study 3a

Study 3a further explores the underlying mechanism of shape–taste crossmodal effects by testing whether they are dependent upon either cognitive resources or mental imagery. To do so, we tested whether the effects are observed when either cognitive or visualization resources are constrained. Although the visual load manipulation also constrains cognitive processing resources, and is thus also a cognitive load manipulation, including both allows us to potentially tease apart the visualization component. If, as we propose, the shape–taste crossmodal effects are relatively automatic, then they should still be observed even under cognitive or visual load conditions. However, if a mental imagery process is required independent of cognitive resources, then the effects may be attenuated under visual but not cognitive load conditions, as Jiang et al. (2016) observed. To simplify the design, we only included sparkling water as the product type.

Method

Participants and design. 266 French college students (175 women; M_{age} = 21.99 years) were randomly assigned to conditions in a 2 (logo shape: angular, rounded) × 3 (mental load: visual, cognitive, no load) × 2 (taste judgment: carbonated, smooth) mixed design, with logo shape and mental load as a between-subjects factor and taste judgment as a within-subjects factor.

Procedure. Participants were informed that they would be completing two separate, unrelated tasks. The first task constituted the manipulation of either visual or cognitive load, both well-established in the literature. Participants were asked to visualize and memorize the placement of a symbol (X) within a grid (visual load, for inhibiting visuospatial working memory; adapted from Jiang et al. 2016), repeat and memorize a 10-digit number series (cognitive load, for inhibiting phonological working memory; adapted from Gilbert, Pelham, and Krull 1988), or were given no memory task (no load). In the visual and cognitive load conditions, participants were asked to maintain the memories of the corresponding materials until they completed the second task.

Next, participants were shown a bottle of sparkling water with either an angular or a rounded logo, and then rated how carbonated and how smooth they thought the drink would taste. The bottles, logos, and scales were the same as those used in Study 1b. As a manipulation check, participants reported whether they "vividly and visually" imagined the taste of the sparkling water (1 = Yes, 0 = No; Web Appendix E). Following that, participants who were in the visual load condition were asked to recreate the grid, and those in the cognitive load condition were asked to write down the 10-digit number. They then provided ratings of task difficulty and effort they expended (1 = not difficult at all/no effort, 9 = very difficult/very much effort).

Results and Discussion

Manipulation checks. The proportion of participants who reported that they had visually imagined the taste of sparkling water was less in the visual load condition (31.82%) than in both the cognitive load condition (45.56%; $\chi^2(1) = 3.54$, $p = .06$, marginal significance) and the no load condition (47.73%; $\chi^2(1) = 4.65$, $p = .03$), with no difference between the latter two load conditions ($\chi^2(1) = .08$, $p = .77$). These results suggest that the visual load effectively inhibited the generation of mental imagery, but the cognitive load did not. Furthermore, there were no differences between the visual and cognitive load conditions in ratings of task difficulty ($M_{visual} = 4.24$, $SD = 1.91$ vs. $M_{cognitive} = 3.76$, $SD = 2.23$, $t(176) = 1.57$, $p = .12$) and effort expended ($M_{visual} = 4.22$, $SD = 1.94$ vs. $M_{cognitive} = 4.07$, $SD = 2.27$, $t(176) = .49$, $p = .63$).

Shape–taste crossmodal effects and mental load. To determine whether logo shapes influenced taste judgments, and whether the shape–taste crossmodal effect differed as a function of mental load, we conducted separate 2 × 3 ANOVAs, with logo shape and mental load as a between-subjects factor, and carbonation and smoothness as dependent variables. The results of these analyses can be seen in Figure 5. (Smoothness ratings are provided in Web Appendix E.)

For the ratings of carbonation, only the main effect of logo shape was significant ($F(1, 260) = 20.75$, $p < .001$). Participants rated the sparkling water as more carbonated when the bottle had an angular logo ($M = 5.50$, $SD = 2.07$) than when it had a rounded logo ($M = 4.38$, $SD = 1.89$), and these effects were invariant across the load conditions. Planned contrasts show that participants rated the sparkling water as more carbonated when the logo was angular than when it was rounded for the visual load condition ($M_{angular\text{-}visual} = 5.50$, $SD = 1.89$ vs. $M_{rounded\text{-}visual} = 4.34$, $SD = 2.02$, $F(1, 260) = 7.40$, $p = .007$), the cognitive load condition ($M_{angular\text{-}cognitive} = 5.43$, $SD = 2.05$ vs. $M_{rounded\text{-}cogniitive} = 4.26$, $SD = 1.86$, $F(1, 260) = 7.72$, $p = .006$), and the no load condition ($M_{angular\text{-}no} = 5.58$, $SD = 2.30$ vs. $M_{rounded\text{-}no} = 4.56$, $SD = 1.83$, $F(1, 260) = 5.73$, $p = .02$), with the control group replicating the findings of Study 1b. In addition, none of the contrasts within shape conditions differed as a function of mental load (ps > .48).

[Insert Figure 5 about here]

The results of Study 3a suggest that shape–taste crossmodal effects on taste judgments are highly automatic. Constraining cognitive processing resources had no effect on shape–taste crossmodal effects, and this finding is consistent with Jiang et al. (2016), who also found that shape–touch crossmodal effects were observed under cognitive load conditions.

However, unlike Jiang et al., we found that inhibiting visualization also had no effect on shape–taste crossmodal effects, which suggests that mental imagery is *not* a necessary process in producing shape–taste crossmodal effects. We have argued that our effects differ from those of Jiang et al. because whereas haptic judgments likely require visualization, taste judgments do not (Kobayashi et al. 2004).

Although the results of Study 3a are consistent with our theoretical reasoning, there are some limitations. First, although the cognitive and visual load manipulations we used are well-established, and our manipulation checks suggest that the manipulations were successful, it is possible that they simply didn't work, one of the problems with reasoning from null findings. Second, the experiment does not directly test our assumption that the default mode for shape–taste crossmodal effects does not require visualization; that is, that consumers do not spontaneously visualize the taste of a product when making taste judgments. Study 3b addresses both of these issues.

Study 3b

Our theorizing proposes that mental imagery is not a necessary stage in generating shape–taste crossmodal effects because individuals are not conditioned to spontaneously generate mental imagery when constructing taste judgments. However, when they do so spontaneously (e.g., for judgments of haptic features such as comfort; Jiang et al. 2016), a visualization process is necessary in generating the crossmodal effects. To test this proposition, we conducted a replication of Study 3a, but also included an additional condition in which we trained participants to visualize prior to making taste judgments, using a procedure adapted from Yágüez et al. (1998). We expect that under visual training conditions, a visual load will eliminate shape–taste crossmodal effects, similar to the findings of Jiang et al. (2016). In contrast, under no visual training (control) conditions, visual load will not inhibit shape–taste crossmodal effects, replicating the findings of Study 3a. To ensure the robustness and generalizability of our findings, we use two types of products (sparkling water and chocolate bar), manipulate their logo or product shape, and measure four pairs of shape–taste correspondences: angular–carbonated, angular–bitter, rounded–smooth, rounded–sweet).

Method

Participants and design. Two hundred forty-two French college students (130 women; M_{age} = 22.93 years) were randomly assigned to conditions in a 2 (visual training: yes, no) × 2 (visual load: yes, no) × 2 (product/logo shape: angular, rounded) × 2 (product type: sparkling water, chocolate bar) × 4 (taste judgment: carbonated, smooth, sweet, bitter) mixed design, with the first three factors as between-subjects factors and the last two factors as within-subjects factors.

Procedure. Participants were informed that they would be completing several unrelated tasks. Prior to completing these tasks, which served as the training manipulations, participants first indicated the extent to which they spontaneously visualize tastes when they evaluate the tastes of foods (3 items, α = .92; see Web Appendix F). The first manipulation was a training task in which half of the participants were trained to visualize tastes when they evaluate the tastes of foods (visual training), whereas the other half did not receive such training (no visual training). In the visual-training condition, participants were required to first visualize the tastes of foods and then evaluate the tastes for 30 foods successively (i.e., 30 trials; Web Appendix F). In the no-visual-training condition, participants evaluated the difficulties for 30 calculation problems successively. We then again measured the extent to which participants rely on visualization when evaluating the tastes of foods with the same three items used at the beginning ($\alpha = .94$), followed by their perceptions of task difficulty and effort they put into the training tasks (1 = not at all, 9 = very much). Next, we manipulated visual load with the same procedure used in Study 3a.

Finally, participants were shown a bottle of sparkling water with either an angular or rounded logo and a chocolate bar with either an angular or a rounded shape (order counterbalanced), and then they rated the expected tastes of the sparkling water (carbonation, smoothness) and the chocolate bar (sweetness, bitterness). The stimuli and scales were the same as those used in Studies 1b and 3a (for sparkling water) and Study 1a and 2 (for chocolate bar).

Results and Discussion

Manipulation checks. To determine whether the visual training successfully influenced participants' reliance on visualization when they evaluated the tastes of foods, we conducted a 2 × 2 mixed-model ANOVA, with visual training as a between-subjects factor and the measure of participants' reliance on visualization before and after the visual training as a within-subjects factor. The main effects of visual training ($F(1, 240) = 31.74$, $p < .001$) and visualization reliance ($F(1, 240) = 143.89$, $p < .001$), and their interaction ($F(1, 240) =$

149.47, $p < .001$), were significant. The before–after measures of visualization show that the visual training increased participants' tendencies to spontaneously rely on visualization ($M_{before} = 4.79$, $SD = 1.61$ vs. $M_{after} = 6.82$, $SD = 1.57$, $F(1, 240) = 293.33$, $p < .001$), but the no-visual-training condition did not ($M_{before} = 4.74$, $SD = 1.62$ vs. $M_{after} = 4.73$, $SD = 1.65$, $F(1, 240) = .03$, $p = .87$).

A between-subjects comparison also confirmed the efficacy of the manipulation, as those who received the visual training subsequently indicated a greater tendency to visualize the tastes of foods ($M_{after} = 6.82$, $SD = 1.58$), compared to those who did not receive visual training ($M_{after} = 4.73$, $SD = 1.65$, $F(1, 240) = 102.18$, $p < .001$). In addition, there were no differences between the visual-training condition and no-visual-training condition in participants' ratings of task difficulty ($M_{visual\text{-}training} = 3.85$, $SD = 2.13$ vs. $M_{no\text{-}visual\text{-}training} = 3.87$, $SD = 1.96$, $t(240) = -.06$, $p = .95$) or effort expended ($M_{visual\text{-}training} = 4.26$, $SD = 2.15$ vs. $M_{no\text{-}visual\text{-}training} = 4.39$, $SD = 2.09$, $t(240) = -.49$, $p = .63$).

Shape–taste crossmodal effects as a function of visual training and visual load (sparkling water). Our primary expectation is that in the absence of any visual training, visual load will have no effect on shape–taste crossmodal effects, and thus the angular logo will increase carbonation judgments and reduce smoothness judgments, replicating the findings of Study 3a. However, when participants have been trained to spontaneously visualize tastes prior to evaluating the tastes of foods, impairing visualization via visual load should attenuate or eliminate the crossmodal effects of shapes on taste judgments. To test this hypothesis, we first conducted separate 2 (visual training) × 2 (logo shape) ANOVAs for sparkling water, with carbonation and smoothness judgments as dependent variables, under visual load conditions only. (Only judgments of carbonation are presented; judgments of smoothness are reported in Web Appendix F.)

The results of this analysis can be seen in Figure 6. For judgments of carbonation, the main effect of logo shape ($F(1, 118) = 3.52$, $p = .063$, marginal significance) and the interaction of logo shape and visual training were significant ($F(1, 118) = 4.13$, $p = .044$). As the left panel of Figure 6 shows, under visual load conditions, when participants did not receive visual training (no-visual-training condition), they expected that the sparkling water would taste more carbonated in the angular logo condition ($M = 5.68$, $SD = 2.12$) than in the rounded logo condition ($M = 4.23$, $SD = 2.21$, $F(1, 118) = 7.64$, $p = .007$). These results indicate that impairing visualization via visual load had no effect, replicating Study 3a. In contrast, when participants were trained to spontaneously rely on visualization (visual-training condition), as the right panel of Figure 6 shows, the crossmodal effect of logo shape on carbonation judgments was eliminated ($M_{angular} = 4.56$, $SD = 1.81$ vs. $M_{rounded} = 4.62$, $SD = 2.01$, $F(1, 118) = .012$, $p = .91$).

[Insert Figure 6 about here]

The results we have presented thus far pertain only to effects under visual load conditions, which is our primary focus. However, we also included a no-load condition in our fully crossed design. These results can be seen in Web Appendix F. In no load conditions, we expected that visual training would not influence the occurrence of the shape–taste crossmodal effects, and thus we expected only a significant main effect for logo shape, replicating the findings of all previous experiments. Our expectation was confirmed. Judgments of carbonation (smoothness) were always greater (lesser) in the angular than in the rounded logo conditions. These findings further attest to the robustness of the shape–taste crossmodal effects.

Shape–taste crossmodal effects as a function of visual training and visual load (chocolate bar). We also examined the shape–taste crossmodal effects as a function of visual training and visual load for chocolate bars. In the interest of brevity, we have reported full results in Web Appendix F. Summarizing, the exact same pattern of effects was observed for the crossmodal effects of product shapes on judgments of bitterness and sweetness of a chocolate bar. For the visual load condition, in the absence of visual training (no-visual-training condition), the crossmodal effects of product shape on taste judgments fully replicate those of Study 1a and Study 2. The angular shaped chocolate bar enhanced expectations of bitterness, whereas the rounded shaped bar enhanced expectations of sweetness, but these crossmodal effects were eliminated when participants were trained to rely on visualization when evaluating the tastes of foods (visual-training condition). In contrast, under no load conditions, there was no effect of visual training on the shape–taste crossmodal effects.

In the current study, by directly conditioning (or not) participants to spontaneously rely on visualization when evaluating tastes of foods and drinks, we demonstrate that whether mental imagery is a necessary stage for generating shape–taste crossmodal effects is dependent on how consumers typically construct taste judgments. Furthermore, consistent with the findings of Study 3a, the results of this study again demonstrate that individuals typically do not go through such a mental imagery process in generating shape–taste crossmodal effects.

General Discussion

Crossmodal correspondences between shape and taste are well-established, but whether, when, and how these correspondences affect taste judgments are not. Drawing upon the spreading activation model of associative memory (Collins and Loftus 1975), across six experiments and one replication, we show that whether shape–taste correspondences influence taste judgments (expectations, experiences) depends on the associative strength in memory between the particular shape and taste. Using two different product categories (bottled water, chocolate bars), we show that even when a particular shape–taste correspondence is statistically significant, the associative strength may not be sufficient to reach the application threshold, and thus will not affect taste judgments. We also show that these effects are very generalizable, with consistent and robust findings across product categories, participant age groups (older children, adults), countries (France, UK, China), and taste judgments (expectations, experiences).

Theoretical Contributions

Our research makes several contributions. At a broad level, we contribute to research on the underlying mechanisms of crossmodal effects on consumer judgments. First, although there is little dispute about the existence of the shape–taste correspondences we investigate (angular vs. rounded shapes on perceptions of carbonated vs. smooth tastes, and bitter vs.

sweet tastes), research on the effects of these correspondences on taste judgments is very inconsistent. Our research provides a potential explanation for the inconsistencies. For example, we demonstrate significant relations between angular shapes and carbonated tastes, and between rounded shapes and smooth tastes, consistent with extant research. However, we also show that the relative associative strengths of these two crossmodal correspondences are different (asymmetrical), and these differences lead to asymmetrical effects on taste judgments: the stronger angular–carbonated association affects both taste expectations and taste experiences, but the relatively weaker rounded–smooth association does not. This is the first research to our knowledge that has linked asymmetrical associative strengths to asymmetrical effects on judgments. Our research points to the importance of understanding the associative strength of the shape–taste correspondences, but is also generalizable to any crossmodal correspondence.

Second, we demonstrate these effects in a child development context. We show that both the strength of the shape–taste correspondences and their application to taste judgments (angular–bitter and rounded–sweet) develop as children age. At younger ages, while children are in the perceptual stage of cognitive development, there is no significant shape–taste correspondence. However, as children start to enter the analytical stage of development (roughly, after age 7), the associations strengthen, and eventually reach the application threshold and affect taste expectations. These findings support the notion that most crossmodal correspondences are learned over time from naturally occurring environmental associations, and the particular age-related thresholds (the age at which the activation and application thresholds occur) are consistent with extant models of children's stages of cognitive development (John 1999; Piaget 1964).

Third, we contribute to research on the automaticity of crossmodal effects. We show that for certain correspondences, such as angular shapes and perceptions of carbonation, the correspondences are highly automatic. Very brief exposures to angular shapes (even subliminal exposure) automatically and spontaneously activate concepts of carbonation, which are then effortlessly applied to taste expectations and taste experiences for a bottled water. In such cases, the effects occur even when cognitive processing resources are constrained. However, for other correspondences, such as rounded shapes and taste judgments of smoothness, exposure to round shapes does not automatically activate smooth taste concepts, and consequently, does not affect these taste judgments.

Fourth, and related, we contribute to research on the role of mental imagery in crossmodal correspondence effects. A cursory inspection of the literature might suggest that the research to date has been mixed, or at least inconclusive. Some research suggests that the application of crossmodal correspondences is highly automatic (e.g., Hagtvedt and Brasel 2016; Yorkston and Menon 2004), whereas other research suggests that it is a more strategic process that requires visualization (e.g., Jiang et al. 2016; Lowe and Haws 2017). We show that these findings are not necessarily contradictory, but pertain to how the judgments are constructed. In constructing some judgments, such as expectation of the taste of a food, consumers do not spontaneously visualize, and thus impeding the visualization process (via visual load) has no effects on downstream judgments. However, when we trained participants to spontaneously visualize tastes, constraining visualization resources eliminated effects on taste judgments. In other cases, such as constructing judgments of how comfortable (Jiang et al. 2016) or big (Lowe and Haws 2017) a product might be, consumers likely attempt to visualize the product, and thus impeding visualization attenuates the effects. Thus, our research provides an explanation that reconciles these seemingly contradictory findings.

Managerial Implications

Our research offers important and actionable managerial implications for marketers. Our findings suggest that marketing managers can effectively leverage certain shape–taste correspondences, under certain conditions. First, our findings suggest that merely determining whether significant shape–taste correspondences exist in a target market is not sufficient. Managers also need to determine whether the associative strengths of the shape–taste correspondences (at an aggregate level) are sufficient to reach the critical application threshold for generating the crossmodal effects of shapes on taste judgments. The associative strengths of shape–taste crossmodal correspondences may differ across populations, cultures, and age groups. As one example, in cultures such as the US, in which bottled water is not that differentiated, there may be little if any association between shapes and taste expectations of sparkling or still waters. However, as our findings demonstrate, in cultures that do have high levels of differentiation (e.g., France), the crossmodal associations are strong and affect taste judgments. Further, our research suggests that testing the associative strengths for such shape–taste crossmodal correspondences is possible and feasible for marketing researchers, either using explicit measures such as the visual analog scales used in the current study, or even using implicit measures such as the Implicit Association Test, which are now relatively easy to implement in marketing research.

Second, our findings suggest that shape–taste crossmodal correspondences can also be effectively leveraged for targeting young consumers. In fact, because children's consumer decisions toward foods and drinks are in general more easily influenced by the product appearance, packaging, and logo than are adults, effective applications of shape–taste crossmodal correspondences in marketing designs of children's brands and products may generate better outcomes in terms of improving consumer experience and product sales. However, our findings also suggest that shape–taste crossmodal correspondences can be only applied to target children who have reached the analytical stage of cognitive development.

Third, our findings regarding the underlying process of shape–taste crossmodal effects, which does not require cognitive resources being involved and a necessary stage of mental imagery, suggests that marketers should be confident that shape–taste crossmodal effects are able to obtain even in highly distracting online and offline shopping environments that consumes substantial phonological and visuospatial working memory resources.

Finally, our findings clearly apply to decisions made for new products, or at least for constructing new logos, packaging, or product shape. Changing logo shapes—or any aspect of an established product—may not be advisable. However, even for established products, existing shapes, such as an angular logo, can be softened, and graphics can be added to packaging, that may leverage any crossmodal correspondence.

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Figure 1

Conceptual Framework

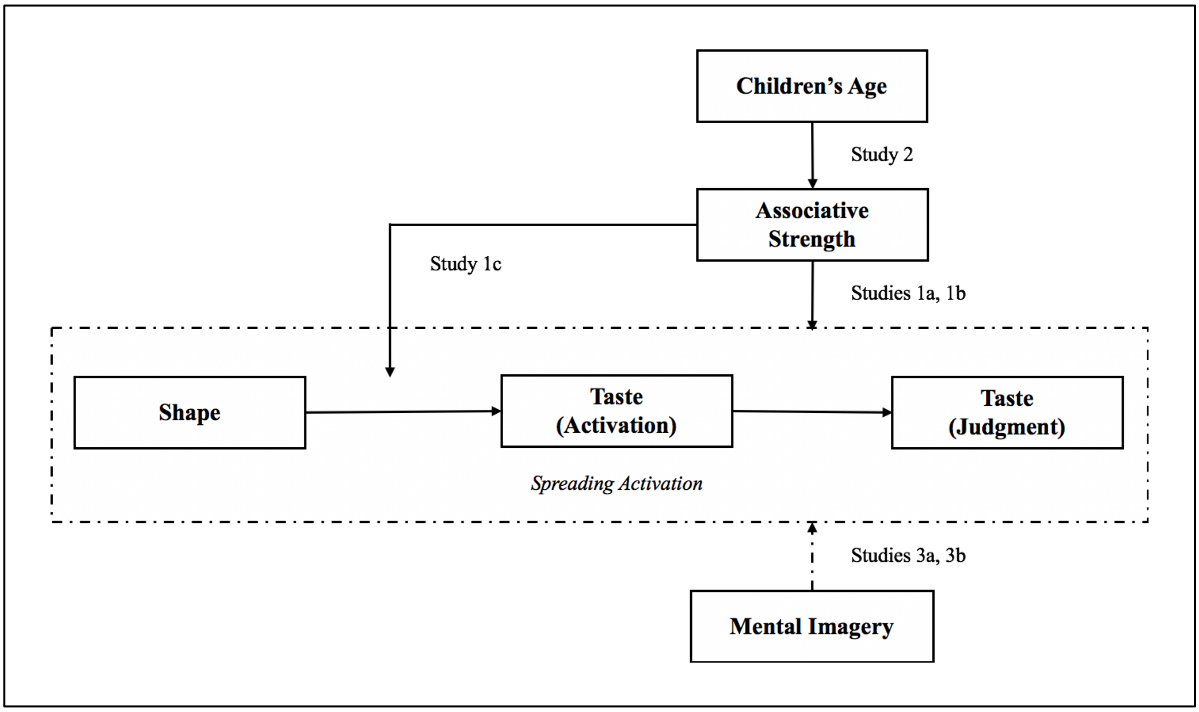


Figure 2

Study 1b: Taste Judgements as a Function of Logo Shape and Drink Type

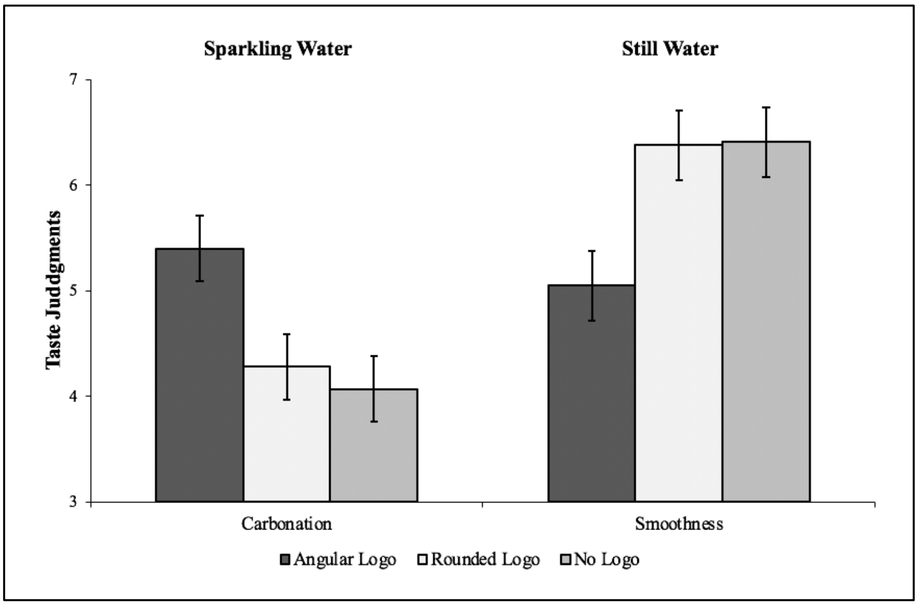


Figure 3

Study 1c: Response Latency as a Function of Shape, Congruity, and Perceptual Level

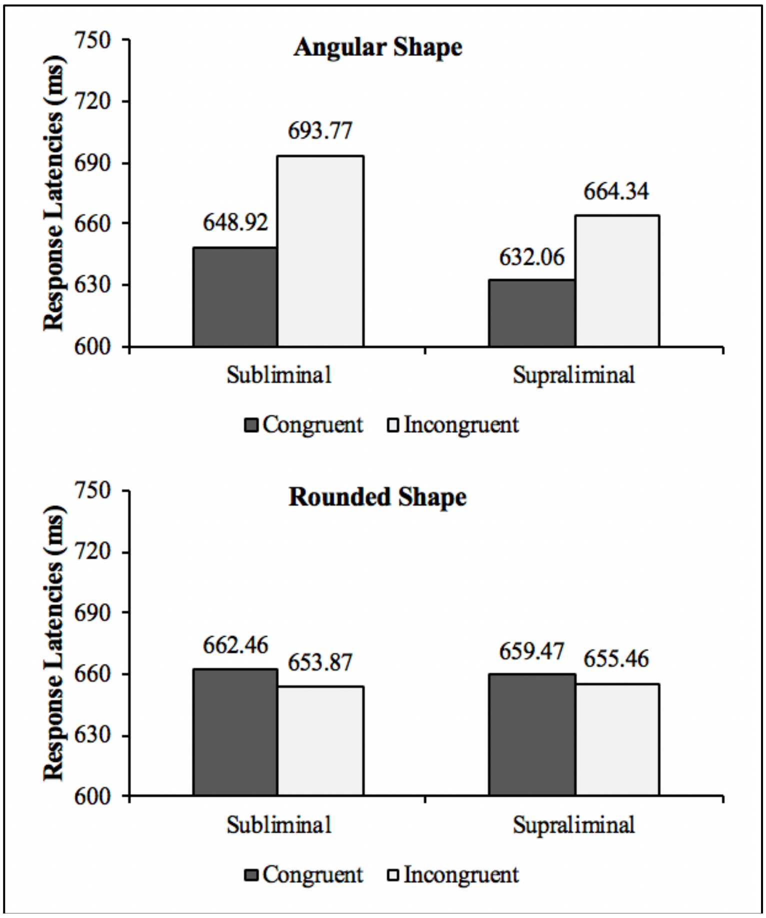


Figure 4

Study 2: Associative Strengths of Shape–Taste Crossmodal Correspondences as a Function of Age

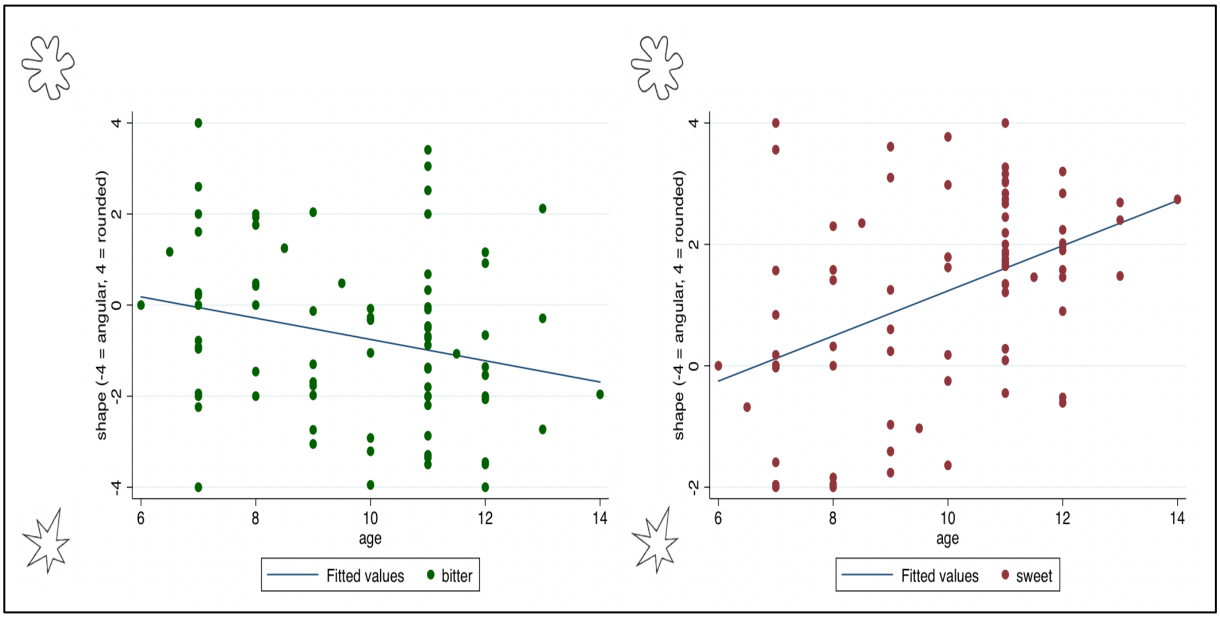


Figure 5

Study 3a: Taste Judgements as a Function of Logo Shape and Mental Load

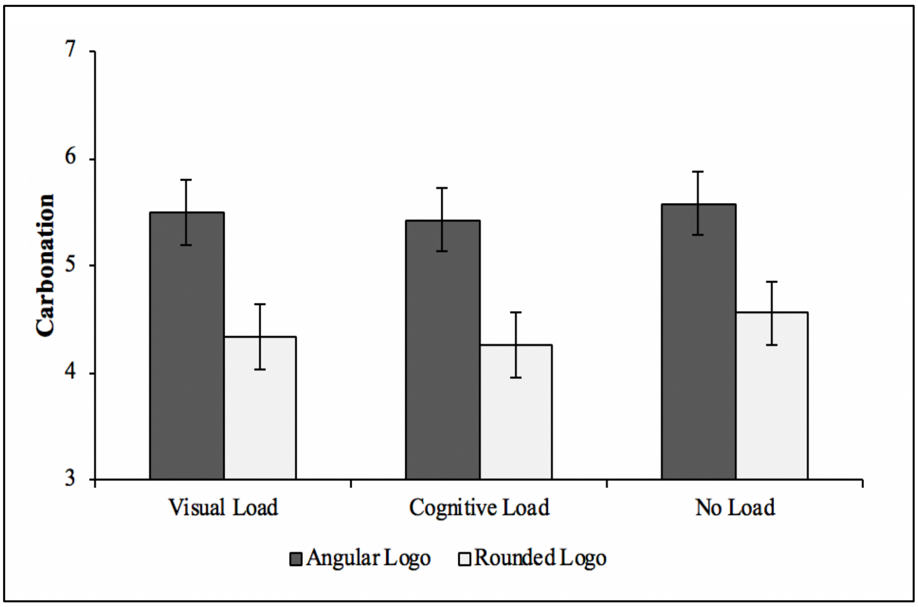


Figure 6

Study 3b: Taste Judgements as a Function of Logo Shape and Visual Training Under Visual Load

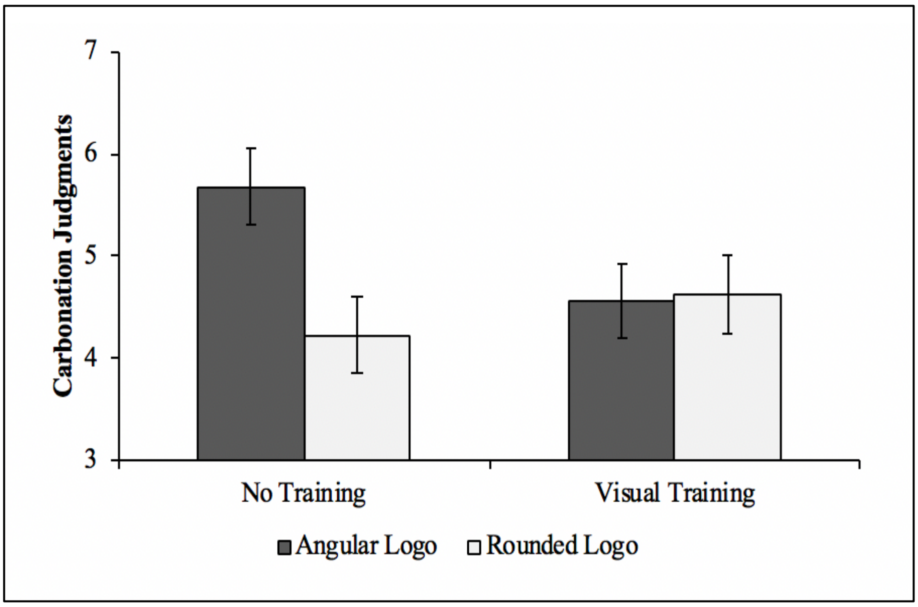


Table 1

Overview of Studies

Study	**Product Category**	**Shape–Taste Crossmodal Correspondence**	**Manipulation of Shape**	**Participants**	**Taste Judgment**	**Key Findings**
Study 1a	Chocolate Bar	Angular-bitter/rounded-sweet	Product shape	British adults	Expectation	Associative strength of shape–taste crossmodal correspondence moderates shape–taste crossmodal effect. Shape–taste crossmodal effect occurs only when associative strength reaches a sufficient application threshold.
Study 1b	Bottled Water	Angular-carbonated/rounded-smooth	Logo shape	French adults	Expectation and experience	At an aggregate level, shape–taste crossmodal effects (on both taste expectations and experience) occur only when the overall associative strength of shape–taste correspondence is above application threshold; otherwise, the effect does not occur, even though the shape–taste crossmodal correspondence is observed.
Study 1c	Bottled Water	Angular-carbonated/rounded-smooth	Abstract shape	French adults	Response latency	Associative strength of shape–taste crossmodal correspondence affects the crossmodal activation of shape on taste concept.
Study 2	Chocolate Bar	Angular-bitter/rounded-sweet	Product shape	Chinese children	Expectation	Age, as the naturally occurring proxy of associative strength, moderates shape–taste crossmodal effects in children.
Study 3a	Bottled Water	Angular-carbonated/rounded-smooth	Logo shape	French adults	Expectation	Generation of shape–taste crossmodal effects does not require cognitive (executive) resources. Generation of shape–taste crossmodal effect does not require mental imagery.
Study 3b	Bottled Water and Chocolate Bar	Angular-carbonated, bitter/rounded-smooth, sweet	Logo shape and product shape	French adults	Expectation	Whether generation of shape–taste crossmodal effect requires mental imagery is dependent on individuals' styles for constructing taste judgments; the styles can be shaped by visual training.

Web Appendix A (Study 1a)

Instruction and Stimuli

In this study, we just want you to know your initial reactions to a chocolate bar.

Please carefully view the picture below of a chocolate bar and then answer a few questions about it.

- How sweet do you think the chocolate bar might be?
  1 = not at all sweet, 9 = very sweet
- How bitter do you think the chocolate bar might be?
  1 = not at tall bitter, 9 = very bitter

- How beautiful is the shape of the chocolate bar?
  1 = not at all beautiful, 9 = very beautiful
- How attractive is the shape of the chocolate bar?
  1 = not at all attractive, 9 = very attractive
- How much do you like the shape of the chocolate bar?
  1 = not at all, 9 = very much

In this very short study, we want to get your first impressions about sensory associations.

- Please drag the slider along the following shape scale to a point that you think best matches a **sweet** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **bitter** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **sweet** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **bitter** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **sweet** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **bitter** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **sweet** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **bitter** taste.

- Please drag the slider along the following scale to a point that you think best matches a **sweet** taste.

Angular shape ____ Rounded shape

- Please drag the slider along the following scale to a point that you think best matches a **bitter** taste.

Angular shape ____ Rounded shape

- What is your gender? □ Male □ Female
- How old are you? ____________________

Web Appendix B (Study 1b)

Detailed Results: Ratings of Smoothness for Sparkling Water and Ratings of Carbonation for Still Water

The results of the other conditions are also instructive. Although smoothness is not a central dimension on which to rate sparkling water, participants nevertheless logically rated the sparkling water as less smooth in the angular logo condition ($M_{angular}$ = 4.15, SD = 1.87) than in the rounded ($M_{rounded}$ = 5.68, SD = 2.12, $t(118)$ = 3.25, p = .002) and no logo conditions ($M_{no\text{-}logo}$ = 5.38, SD = 2.27, $t(118)$ = 2.63, p = .01), with no difference between the latter two conditions ($t(118)$ = .65, p = .52). These results again suggest that the crossmodal effects of logo shapes on smoothness judgments are driven by the angular logo, with no effect of the rounded logo, which does not differ from the no-logo control group.

For the carbonation judgments of the still water, participants' ratings for the still water's carbonation were at a very low level and did not differ between the logo conditions ($M_{angular}$ = 1.85, SD = .88, $M_{rounded}$ = 1.73, SD = .99, $M_{no\text{-}logo}$ = 1.71, SD = 1.03, $F(2, 119)$ = .28, p = .76), which is consistent with the actual features of still water and suggests good discriminant validity of our measurements.

Instruction and Stimuli

Survey 1-3: Sparkling Water—Angular/Rounded/No Logo

A beverage company is launching a new sparkling water and the company needs to design the packaging for this product. We would like you to help this company to evaluate the packaging. Please first see the following packaging figure and then answer the questions that follow.

- What do you think the taste of the new drink might be?
  1 = not at all carbonated, 9 = very carbonated
  1 = not at all smooth, 9 = very smooth

- How beautiful is the LOGO? <u>(except for the no logo condition)</u>
  1 = not at all beautiful, 9 = very beautiful
- How attractive is the LOGO?
  1 = not at all attractive, 9 = very attractive
- How much do you like the LOGO?
  1 = not at all, 9 = very much

- Please drag the slider along the scale to a point that you think best matches your experience when drinking sparkling water.

- Please drag the slider along the scale to a point that you think best matches your experience when drinking still water.

- What is your gender? □ Male □ Female
- How old are you? ____________________

Survey 4-6: Still Water—Angular/Rounded/No Logo

A beverage company is launching a new mineral water and the company needs to design the packaging for this product. We would like you to help this company to evaluate the packaging. Please first see the following packaging figure and then answer the questions that follow.

- What do you think the taste of the new drink might be?
  1 = not at all smooth, 9 = very smooth
  1 = not at all carbonated, 9 = very carbonated

- How beautiful is the LOGO? <u>(except for the no logo condition)</u>
  1 = not at all beautiful, 9 = very beautiful
- How attractive is the LOGO?
  1 = not at all attractive, 9 = very attractive
- How much do you like the LOGO?
  1 = not at all, 9 = very much

- Please drag the slider along the scale to a point that you think best matches your experience when drinking sparking water.

- Please drag the slider along the scale to a point that you think best matches your experience when drinking still water.

- What is your gender? □ Male □ Female
- How old are you? ____________________

Supplementary Study for Study 1b

The objective of the supplementary study was to demonstrate the generalizability of the findings of Study 1b by replicating the effects with actual taste experience following a taste test and using a different manipulation of logo shape. Based on the results of Study 1b, we expected that the angular logo would influence experience of carbonation, but that the rounded logo would not influence experience of smoothness.

Method

Participants and design. Two hundred ninety-three French college students (176 women; M_{age} = 22.72 years) who participated in return for 2€ were randomly assigned to conditions in a 3 (logo shape: angular, rounded, no logo) × 2 (drink type: sparkling, still water) × 2 (taste judgment: carbonated, smooth) mixed design, with logo shape and drink type as between-subjects factors and taste judgment as a within-subjects factor.

Procedure. In a study ostensibly to test a new bottled drink, participants were told that the product was in an early stage of testing, and it did not yet have a brand name, just a rough logo (in the logo conditions only), and that we were only interested in their taste ratings. Participants were individually tested in a room that had been set up in advance. Each participant was given a bottle of either sparkling or still water, with either an angular logo, rounded logo, or no logo. Just prior to their entry into the room, the bottle had been filled with a popular brand of either still or sparkling water. Participants were provided written instructions indicating that we wanted them to taste the product and then answer some questions about it. Next, participants tasted the water and rated how carbonated and smooth they thought the drink tasted, each along a 16 cm line scale (anchors: not at all, very). (Numbers in results section indicate length in cm, range 0-16). Finally, participants indicated their attitudes toward the logo (except in the no-logo condition) with the same 3-item scale used in the previous studies ($\alpha = .93$).

Results and Discussion

A 2 (logo shape) × 2 (drink type) ANOVA confirmed that there were no differences in participants' liking of the logos across conditions (*p*s > .37).

Shape–taste crossmodal effects. To test whether logo shape influenced taste experience, we conducted separate 3 (logo shape: angular, rounded, no logo) × 2 (taste judgment: carbonated, smooth) mixed-model ANOVAs, with logo shape as a between-subjects factor and taste judgment as a within-subjects factor, for sparkling and for still water.

For sparkling water, the main effect of taste judgment was significant ($F(1, 143) = 85.42$, $p < .001$), as was the interaction of logo shape and taste judgment ($F(2, 143) = 5.13$, $p = .007$). As expected, participants thought the sparkling water tasted more carbonated when the bottle had an angular logo ($M_{angular} = 13.48$, $SD = 2.44$) than when the bottle (with the exact same sparkling water) had no logo ($M_{no\ logo} = 12.33$, $SD = 2.64$, $t(143) = 2.14$, $p = .034$) or had a rounded logo ($M_{rounded} = 12.17$, $SD = 2.89$, $t(143) = 2.42$, $p = .017$). The latter two conditions did not differ ($t(143) = -.30$, $p = .77$). These results suggest that the angular logo increased experience of how carbonated the water tasted, but that the rounded logo had no effect, replicating Study 1b.

For still water, the main effect of taste judgment ($F(1, 144) = 1462.23$, $p < .001$) and the interaction ($F(2, 144) = 3.43$, $p = .035$) were significant. As with Study 1b, participants thought the still water tasted more smooth when the bottle had a rounded logo ($M = 12.90$, $SD = 2.88$) than when it had an angular logo ($M = 11.34$, $SD = 3.99$; $t(144) = 2.27$, $p = .025$). However, participants' experience of smooth taste did not differ between the rounded logo ($M = 12.90$, *SD*

= 2.88) and no logo conditions (*M* = 12.81, *SD* = 3.24; $t(144) = .13$, $p = .89$), but they rated smoothness as less in the angular than in the no logo conditions ($t(144) = 2.13$, $p = .035$). These results suggest that the rounded logo had no effect on experience of smoothness in the still water, but the angular logo reduced experience of smoothness, and also replicate the findings of Study 1b.

Also consistent with Study 1b, participants thought the sparkling water tasted less smooth in the angular logo condition ($M_{angular} = 7.05$, $SD = 3.82$) than in the rounded ($M_{rounded} = 8.71$, $SD = 3.75$, $t(143) = -2.04$, $p = .04$) and no logo conditions ($M_{no\text{-}logo} = 9.24$, $SD = 4.47$, $t(143) = -2.70$, $p = .008$), with no difference between the latter two conditions ($t(143) = -.65$, $p = .52$). For the ratings of carbonation of the still water, they were again very low, and did not differ between logo conditions ($M_{angular} = .67$, $SD = 1.88$, $M_{rounded} = .52$, $SD = 1.26$, $M_{no\text{-}logo} = .41$, $SD = 1.07$, $F(2, 144) = .40$, $p = .67$).

Instruction and Stimuli

We are working on a project developing a new bottled water and we wanted to ask if you would be willing to try it. It is still in the very early stages; we don't even have a name for it yet, just a rough logo (for logo conditions only).

But what we are interested in is what you think of the taste. Would you taste the water and then just answer a few questions about it? When you taste the drink, please keep it in your mouth for 5 seconds to sufficiently experience it.

The bottles with different logos

1. How carbonated do you think the taste of the drink is? Please rate on the following scale to a point that you think best reflects your taste experience.

not at all carbonated very carbonated

2. How smooth do you think the taste of the drink is? Please rate on the following scale to a point that you think best reflects your taste experience.

not at all smooth very smooth

3. How beautiful is the LOGO?

not at all beautiful very beautiful

4. How attractive is the LOGO?

not at all attractive very attractive

5. How much do you like the LOGO?

not at all very much

What is your gender? □ Male □ Female
How old are you? ______________________

Web Appendix C (Study 1c)

Detailed Procedure

In the experiment, we used a masked priming paradigm in which an angular or rounded shape was quickly presented and hidden between a forward and a backward mask. The task consisted of four blocks that differed in the duration of the stimulus presentation and the task purpose: 12 *ms* (subliminal presentation) in the first and third blocks and 112 *ms* (supraliminal presentation) in the second and last blocks. A stimulus presentation of 12 *ms* is generally considered to be subliminal (Greenwald, Draine, and Abrams 1996).

The first two blocks were used to test the crossmodal activation of shapes on taste concepts and the last two blocks were used as manipulation checks for the subliminal and supraliminal presentation. Specifically, within each block, shape and congruity were manipulated (crossed) over 32 trials (blocks 1 and 2) and 20 trials (blocks 3 and 4), for a total of 128 trials for the first two blocks and 80 trials for the last two blocks. For the selection of shape stimuli, we designed four homogeneous angular and rounded shapes, and each of the four were randomly displayed within shape conditions. The stimuli used for conveying taste concepts were the most popular bottled waters (sparking and still waters) in France. The shapes, bottled waters, and congruity pairings were randomly distributed over the trials.

During the experiment, participants were seated in front of a computer screen with a resolution of 1280 × 800 and refresh rate of 60 Hz, at a 60-cm distance. At the beginning of blocks 1 and 2, participants were instructed to carefully watch a series of pictures and press “f” or “j” key with their index fingers when they saw a sparkling or a still water. They were then given a learning task to familiarize with the shapes, bottled drinks, and masked images. For the first two blocks, each trial began with the presentation of a central cross that was used to fixate the participant's gaze, followed by the presentation of the masked stimulus. Next, participants were shown either a sparkling or a still water and asked to respond (by pressing the appropriate key) as soon as they recognized the stimulus. The response latency and the error rate of each trial were recorded. The procedure for blocks 3 and 4 were identical to the first two blocks except participants were asked to indicate which shape had been presented between the two masks for checking whether the subliminal and supraliminal manipulations were successful.

Instruction and Stimuli

General Instruction

Welcome to our experiment.

The experiment consists of four simple tasks. During task 1 and 2, a red cross "+" will be first displayed in the center of the screen, reminding you that the experiment will start. At this moment, please stay focused and stare at the center of the screen, after that, you will see a series of black and white pictures, and then two types of drinks - sparkling and still water (see their packages below) - will be randomly displayed on the screen. When you see a sparkling water, please press "f" key; while when you see a still water, please press "j" key. Please react as quickly and accurately as possible.

Sparkling water – "f" key

Still water – "j" key

The instructions of task 3 and 4 will be presented after you complete the first two tasks. If you are already familiar with these sparkling and still waters, next we will give you a quiz to test your familiarity. When you are ready, please press the space-bar to enter the quiz.

Instruction for Quiz

Welcome to the quiz.

Let us remind you again, when you see a sparkling water, please press “f” key; while when you see a still water, please press “j” key. Please stay focused and react as quickly and accurately as possible.

Sparkling water – “f” key

Still water – “j” key

Note that, if your accuracy rate is less than 80%, then you will be asked to redo the quiz until you reach the standard.

Now, please put your left index finger on “f” key and your right index finger on “j” key. If you are ready, please press the space-bar to start.

Instruction for Task 1

Congratulations! Now you are already very familiar with the sparkling and still waters. Next, you will enter task 1. Let us remind you again, during this task, a red cross “+” will be first displayed in the center of the screen, reminding you that the experiment will start. At this moment, please stay focused and stare at the center of the screen, after that, you will see a series of black and white pictures, and then two types of drinks - sparkling and still water - will be randomly displayed on the screen. When you see a sparkling water, please press “f” key; while when you see a still water, please press “j” key. Please react as quickly and accurately as possible.

If you have already understood the above instruction, please put your left index finger on “f” key and right index finger on “j” key.

Please remember, sparkling water - “f” key; still water - “j” key. If you are ready, please press the space-bar to start the task.

Instruction for Task 1 Ending

Congratulations! You have successfully completed task 1. If you feel a little bit tired now, please have a short rest. When you feel good, please press the space-bar to continue.

Instruction for Task 2

Welcome to the second task!

Similar to task 1, during this task, a red cross "+" will be first displayed in the center of the screen, reminding you that the experiment will start. At this moment, please stay focused and stare at the center of the screen, after that, you will see a series of black and white pictures, and then two types of drinks - sparkling and still water - will be randomly displayed on the screen. When you see a sparkling water, please press "f" key; while when you see a still water, please press "j" key. Please react as quickly and accurately as possible.

If you have already understood the above instruction, please put your left index finger on "f" key and right index finger on "j" key.

Please remember, sparkling water - "f" key; still water - "j" key. If you are ready, please press the space-bar to start the task.

Instruction for Task 2 Ending

Congratulations! You have successfully completed task 2. If you feel a little bit tired now, please have a short rest. When you feel good, please press the space-bar to continue.

Instruction for Task 3

Welcome to the third task!

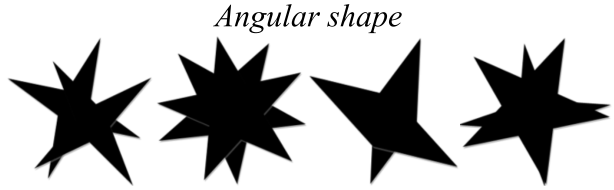
During this task, a red cross "+" will be first displayed in the center of the screen, reminding you that the experiment will start. At this moment, please stay focused and stare at the center of the screen, after that, you will see a series of black and white pictures, please try to identify what you see that is hidden in the black and white dot masks.

- If you **saw** an **angular** shape, please press **"f"** key.
- If you **guess** it was an **angular** shape, please press **"v"** key.
- If you **saw** a **rounded** shape, please press **"j"** key.
- If you **guess** it was a **rounded** shape, please press **"n"** key.

Currently, you do not have to remember all these reactions, we will also remind you later. If you are ready, please press the space-bar to start the task.

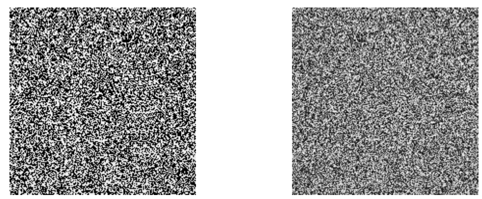
Stimuli used in this task

Angular shape



Rounded shape

Black-white dot masks



Instruction for Reaction

Please report the shape which was hidden in the black and white dot masks.

- **Saw** an **angular** shape – please press **"f"** key
- **Guess** it was an **angular** shape – please press **"v"** key
- **Saw** a **rounded** shape – please press **"j"** key
- **Guess** it was a **rounded** shape – please press **"n"** key

Instruction for Task 3 Ending

Congratulations! You have successfully completed task 3. If you feel a little bit tired now, please have a short rest. When you feel good, please press the space-bar to continue.

Instruction for Task 4

Welcome to the fourth task!

Similar to task 3, during this task, a red cross "+" will be first displayed in the center of the screen, reminding you that the experiment will start. At this moment, please stay focused and stare at the center of the screen, after that, you will see a series of black and white pictures, please try to identify what you see that is hidden in the black and white dot masks.

- If you **saw** an **angular** shape, please press **"f"** key.
- If you **guess** it was an **angular** shape, please press **"v"** key.
- If you **saw** a **rounded** shape, please press **"j"** key.
- If you **guess** it was a **rounded** shape, please press **"n"** key.

Currently, you do not have to remember all these reactions, we will also remind you later. If you are ready, please press the space-bar to start the task.

Stimuli are the same ones used in task 3

Instruction for Reaction

Please report the shape which was hidden in the black and white dot masks.

- **Saw** an **angular** shape – please press **"f"** key
- **Guess** it was an **angular** shape – please press **"v"** key
- **Saw** a **rounded** shape – please press **"j"** key
- **Guess** it was a **rounded** shape – please press **"n"** key

Instruction for Ending

Congratulations! You have successfully completed all four tasks. Thanks again for your participation! At the end, please complete several simple questions which are presented on the paper.

Web Appendix D (Study 2)

Instruction and Stimuli

Thank you so much for participating in our survey! In this study, we just want to know your initial reactions to a chocolate bar. Please carefully view the picture below of a chocolate bar and then answer a few questions about it.

- How sweet do you think the chocolate bar might be?
  1 = not at all sweet, 9 = very sweet
- How bitter do you think the chocolate bar might be?
  1 = not at tall bitter, 9 = very bitter

- How beautiful is the shape of the chocolate bar?
  1 = not at all beautiful, 9 = very beautiful
- How attractive is the shape of the chocolate bar?
  1 = not at all attractive, 9 = very attractive
- How much do you like the shape of the chocolate bar?
  1 = not at all, 9 = very much

In this very short study, we want to get your first impressions about sensory associations.

- Please drag the slider along the following shape scale to a point that you think best matches a **sweet** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **bitter** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **sweet** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **bitter** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **sweet** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **bitter** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **sweet** taste.

- Please drag the slider along the following shape scale to a point that you think best matches a **bitter** taste.

- What is your gender? □ Male □ Female
- How old are you? ______________________

Web Appendix E (Study 3a)

Supplementary Results: Ratings of Smoothness for Sparkling Water

For the ratings of smoothness, again only the main effect of logo shape was significant ($F(1, 260) = 23.76$, $p < .001$). Participants rated the sparkling water as less smooth when the bottle had an angular logo ($M = 4.35$, $SD = 2.02$) than when it had a rounded logo ($M = 5.53$, $SD = 1.92$), and these effects were also invariant across the load conditions. Planned contrasts show participants rated the sparkling water as less smooth when the logo was angular than when it was rounded for the visual load condition ($M_{angular\text{-}visual} = 4.30$, $SD = 1.84$ vs. $M_{rounded\text{-}visual} = 5.48$, $SD = 1.81$, $F(1, 260) = 7.77$, $p = .006$), the cognitive load condition ($M_{angular\text{-}cognnitive} = 4.41$, $SD = 2.03$ vs. $M_{rounded\text{-}cognitive} = 5.50$, $SD = 1.97$, $F(1, 260) = 6.77$, $p = .01$), and the no-load condition ($M_{angular\text{-}no} = 4.33$, $SD = 2.23$ vs. $M_{rounded\text{-}no} = 5.63$, $SD = 2.02$, $F(1, 260) = 9.32$, $p = .003$), with the control condition replicating the findings of Study 1b. In addition, none of the contrasts within shape conditions differed as a function of mental load (*p*s > .72).

Instruction and Stimuli

Survey 1 and 2: Angular and Rounded Logo—Visual Load

Dear participants,

Welcome to our experiment. In the experiment, you will complete two tasks.

In the first task, we will show you a 5 X 5 grid image with a symbol “X” in some of the cells. Please visualize this picture in your mind and remember the positions of the cells that have the symbol “X” in the table. And please try to keep this image in your mind continually until you complete the second task, because we will ask you to recreate the grid image at the end.

In the second task, we will show you a packaging figure which is designed for a new bottled sparkling water, and then please answer several simple questions based on your feelings of the packaging. But at the same time, please do not forget to keep the image you memorized in the first task in your mind.

At the end of this experiment, we will ask you to recreate the table and point out which cells have a symbol “X.”

Welcome to the first task. Please see the following grid image and try to visualize it in your mind and remember the positions of the cells that have the symbol "X" in the table. Please do not take notes on paper in order to memorize this table. When you feel that you have remembered this picture, please enter in the next task. Meanwhile, please try to keep this image in your mind continually until you complete the second task, because we will ask you to recreate the grid image at the end.

		X		
	X			**X**
		X	**X**	
X	**X**		**X**	
		X		**X**

Welcome to the second task! Please see the packaging figure first, and then answer some simple questions by your intuition.

- How carbonated do you think the taste of the new sparkling water might be?
  1 = not at all carbonated, 9 = very carbonated
- How smooth do you think the taste of the new sparkling water might be?
  1 = not at tall smooth, 9 = very smooth

- From your first look on the packaging to when we asked you to rate the taste of the new drink, did you vividly and visually imagine the taste of the sparkling water, for example, visually imagining how many bubbles does the drink have or a scene expressing your taste experience when you drink the new sparkling water.
  □ Yes
  □ No

- Please indicate which cells have the symbol "X" in the following matrix (each point represents a cell):

- How difficult do you think this visual memory task is?
  1 = not at all difficult, 9 = very difficult
- How much effort did you put into this visual memory task?
  1 = no effort, 9 = very much effort

- What is your gender? □ Female □ Male
- How old are you? ______________________

Survey 3 and 4: Angular and Rounded logo—Traditional Cognitive Load

Dear participants,

Welcome to our experiment. In the experiment, you will complete two tasks.

In the first task, we will show you a series of numbers, please memorize these numbers in order and try to repeat these numbers in your mind continually until you complete the second task, because we will ask you to report the numbers at the end.

In the second task, we will show you a packaging figure which is designed for a new bottled sparkling water, and then please answer several simple questions based on your feelings of the packaging. But at the same time, please do not forget to repeat the numbers you memorized in the first task in your mind.

At the end of this experiment, we will ask you to report the numbers in its order.

Welcome to the first task. Please see the following numbers, and memorize them in order. Please do not take notes on paper. When you feel that you have remembered these numbers, please enter in the next task. Meanwhile, please try to repeat these numbers in your mind continually until you complete the second task, because we will ask you to report the numbers at the end.

3 6 4 2 9 8 7 0 1 5

Welcome to the second task! Please see the packaging figure first, and then answer some simple questions by your intuition.

- How carbonated do you think the taste of the new sparkling water might be?
  1 = not at all carbonated, 9 = very carbonated
- How smooth do you think the taste of the new sparkling water might be?
  1 = not at tall smooth, 9 = very smooth

- From your first look on the packaging to when we asked you to rate the taste of the new drink, did you vividly and visually imagine the taste of the sparkling water, for example, visually imaging how many bubbles does the drink have or a scene expressing your taste experience when you drink the new sparkling water.
  □ Yes
  □ No

- Please write down the numbers in its order in the following box:

- How difficult do you think this numerical memory task is?
  1 = not at all difficult, 9 = very difficult
- How much effort did you put into this numerical memory task?
  1 = no effort, 9 = very much effort

- What is your gender? □ Female □ Male
- How old are you? ______________________

Survey 5 and 6: Angular and Rounded Logo—No Load

Dear participants,

Welcome to our experiment. In the experiment, we will show you a packaging figure which is designed for a new bottled sparkling water, and then please answer several simple questions based on your feelings of the packaging.

- How carbonated do you think the taste of the new sparkling water might be?
  1 = not at all carbonated, 9 = very carbonated
- How smooth do you think the taste of the new sparkling water might be?
  1 = not at tall smooth, 9 = very smooth

- From your first look on the packaging to when we asked you to rate the taste of the new drink, did you vividly and visually imagine the taste of the sparkling water, for example, visually imaging how many bubbles does the drink have or a scene expressing your taste experience when you drink the new sparkling water.
  □ Yes
  □ No

- What is your gender? □ Female □ Male
- How old are you? ______________________

Web Appendix F (Study 3b)

Detailed Results

***Sparkling water*. The effects of visual training for shape–taste crossmodal effects under visual load**

The ratings on smoothness for sparkling water

The same pattern of results was observed for judgments of smoothness. The main effect of logo shape ($F(1, 118) = 3.28$, $p = .073$, marginal significance) and the interaction of logo shape and visual training ($F(1, 118) = 3.82$, $p = .05$), were significant. Under visual load conditions, in the absence of visual training (no-visual-training condition), participants expected that the sparkling water would taste less smooth in the angular logo condition ($M = 4.10$, $SD = 2.21$) than in the rounded logo condition ($M = 5.53$, $SD = 2.32$, $F(1, 118) = 7.10$, $p = .009$), again replicating the findings of Study 3a. In contrast, for the visual-training condition, the crossmodal effect of logo shape on smoothness judgments was eliminated ($M_{angular}$ = 5.47, *SD* = 1.80 vs. M_{round} = 5.41, *SD* = 2.08, *F*(1, 118) = .01, *p* = .92).

<u>*Sparkling water.* The effects of visual training for shape–taste crossmodal effects under no load</u>

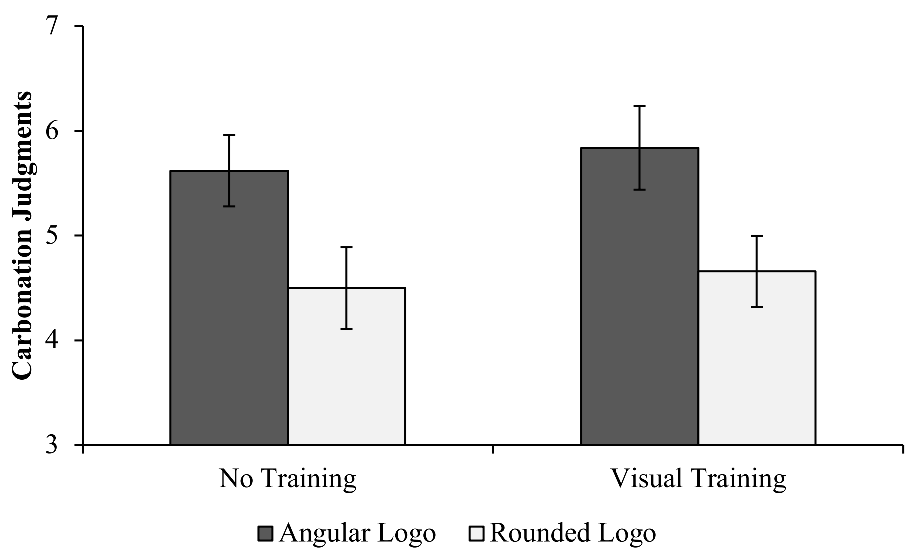
We conducted separate 2 (visual training) × 2 (logo shape) ANOVAs for sparkling water, with carbonation and smoothness judgments as the dependent variables, under no load conditions only.

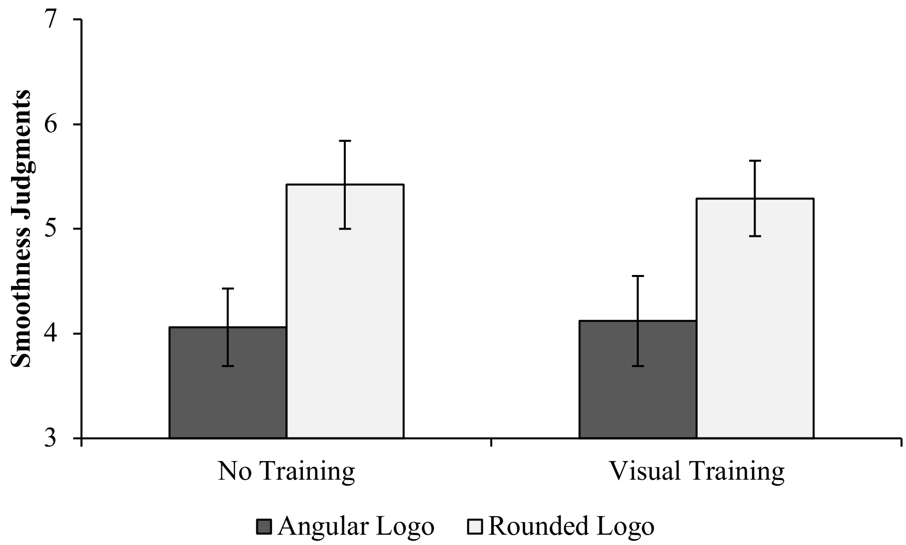
The results of this analysis can be seen in Figure S1. For judgments of carbonation, only the main effect of logo shape was significant (*F*(1, 116) = 9.83, *p* = .002). Specifically, under no load conditions, participants expected that the sparkling water would taste more carbonated in the angular logo condition than in the rounded logo condition, for both when they did not receive visual training (top left panel; $M_{angular}$ = 5.62, *SD* = 1.81 vs. $M_{rounded}$ = 4.50, *SD* = 2.18, *F*(1, 116) = 4.66, *p* = .033) and received visual training (top right panel; $M_{angular}$ = 5.84, *SD* = 1.97 vs. $M_{rounded}$ = 4.66, *SD* = 2.01, *F*(1, 116) = 5.17, *p* = .025).

The same pattern of results was observed for judgments of smoothness. Only the main effect of logo shape was significant (*F*(1, 116) = 9.83, *p* = .002). Specifically, under no load conditions, participants expected that the sparkling water would taste less smooth in the angular logo condition than in the rounded logo condition, for both when they did not receive visual training (bottom left panel; $M_{angular}$ = 4.06, *SD* = 1.81 vs. $M_{rounded}$ = 5.42, *SD* = 2.50, *F*(1, 116) = 5.98, *p* = .016) or received visual training (bottom right panel; $M_{angular}$ = 4.12, *SD* = 2.07 vs. $M_{rounded}$ = 5.29, *SD* = 2.20, *F*(1, 116) = 4.32, *p* = .04).

Figure S1

Study 3b: Taste Judgements as a Function of Logo Shape and Visual Training Under No Load





Chocolate bar. The effects of visual training for shape–taste crossmodal effects under visual load

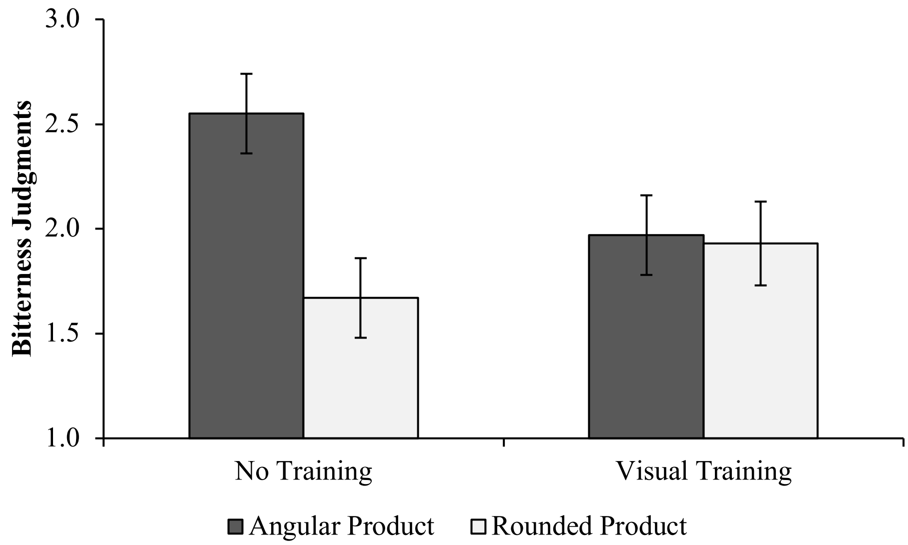
We conducted separate 2 (visual training) × 2 (product shape) ANOVAs for chocolate bar, with sweetness and bitterness judgments as the dependent variables, under visual load conditions only.

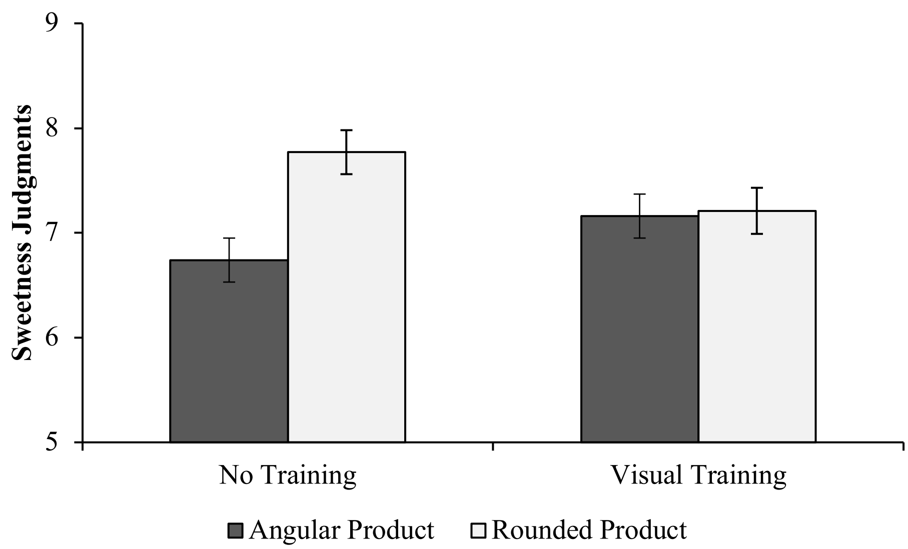
The results of this analysis can be seen in Figure S2. For judgments of bitterness, the main effect of product shape ($F(1, 118) = 5.70$, $p = .019$) and the interaction of product shape and visual training were significant ($F(1, 118) = 4.81$, $p = .03$). As the top left panel shows, under visual load conditions, in the absence of visual training, participants expected that the chocolate bar would taste more bitter in the angular shape condition ($M = 2.55$, $SD = 1.03$) than in the rounded shape condition ($M = 1.67$, $SD = .92$, $F(1, 118) = 10.50$, $p = .002$). In contrast, for visual training condition (top right panel), the expectations of bitter taste did not significantly differ between angular ($M = 1.97$, $SD = 1.12$) and rounded shape conditions ($M = 1.93$, $SD = 1.16$, $F(1, 118) = .019$, $p = .89$).

The same pattern of results was observed for judgments of sweetness, the main effect of product shape ($F(1, 118) = 6.40$, $p = .013$) and the interaction of product shape and visual training were significant ($F(1, 118) = 5.25$, $p = .024$). As the bottom left panel shows, under visual load conditions, when participants did not receive visual training, they expected that the chocolate bar would taste more sweet in the rounded shape condition ($M = 7.77$, $SD = 1.04$) than in the angular shape condition ($M = 6.74$, $SD = 1.09$, $F(1, 118) = 11.64$, $p = .001$). In contrast, when participants were trained to spontaneously visualize taste (bottom right panel), the expectations of sweet taste did not differ between rounded ($M = 7.21$, $SD = 1.26$) and angular shape conditions ($M = 7.16$, $SD = 1.27$, $F(1, 118) = .028$, $p = .87$).

Figure S2

Study 3b: Taste Judgements as a Function of Product Shape and Visual Training Under Visual Load





Chocolate bar. The effects of visual training for shape–taste crossmodal effects under no load

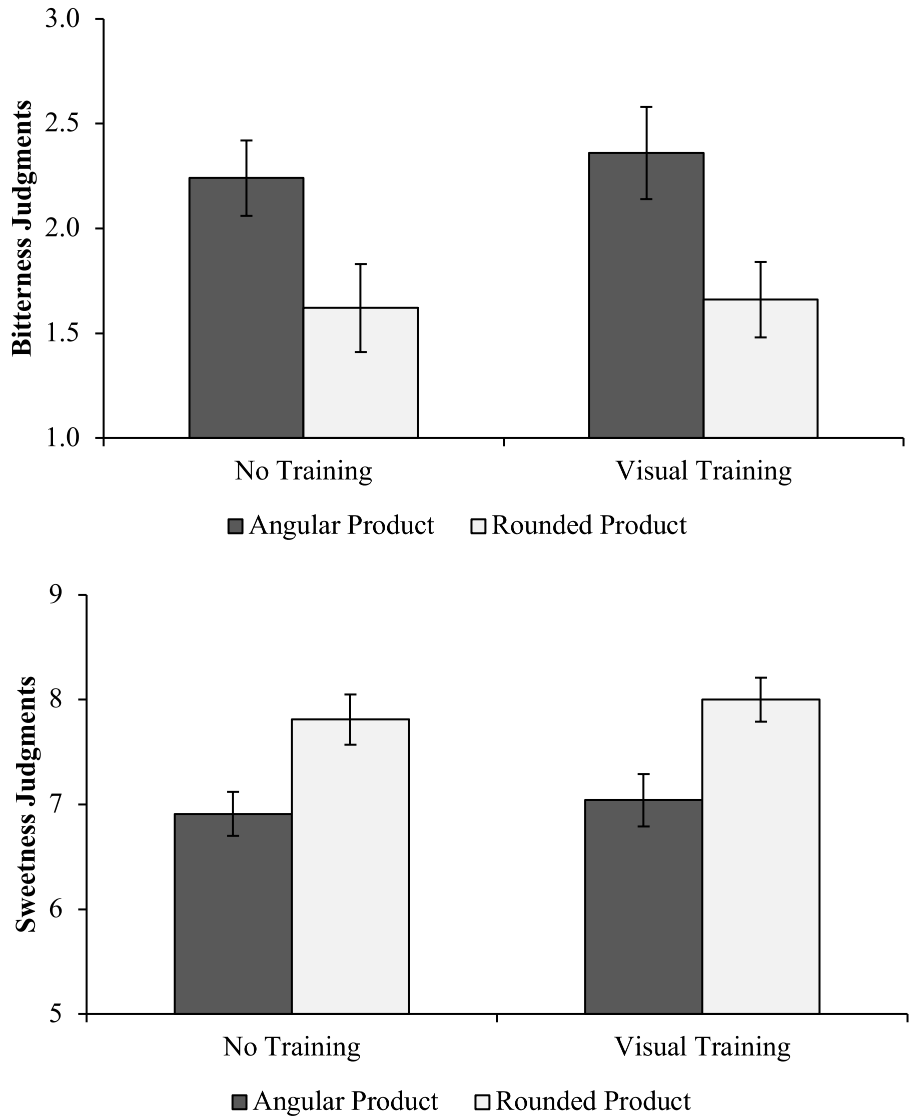
We conducted separate 2 (visual training) × 2 (product shape) ANOVAs for chocolate bar, with sweetness and bitterness judgments as the dependent variables, under no load conditions only.

The results of this analysis can be seen in Figure S3. For judgments of bitterness, only the main effect of product shape was significant ($F(1, 116) = 11.11$, $p = .001$). Specifically, under no load conditions, participants expected that the chocolate bar would taste more bitter in the angular shape condition than in the rounded shape condition, for both when they did not receive visual training (top left panel; $M_{angular} = 2.24$, $SD = 1.21$ vs. $M_{rounded} = 1.62$, $SD = .80$, $F(1, 116) = 4.90$, $p = .029$) or visual training (top right panel; ($M_{angular} = 2.36$, $SD = 1.25$ vs. $M_{rounded} = 1.66$, $SD = .97$, $F(1, 116) = 6.24$, $p = .014$).

The same pattern of results was observed for judgments of sweetness. Only the main effect of product shape was significant ($F(1, 116) = 16.66$, $p < .001$). Specifically, under no load conditions, participants expected that the chocolate bar would taste more sweet in the rounded shape condition than in the angular shape condition, for both when they did not receive visual training (bottom left panel; $M_{rounded} = 7.81$, $SD = 1.13$ vs. $M_{angular} = 6.91$, $SD = 1.44$, $F(1, 116) = 7.81$, $p = .006$) or received visual training (bottom right panel; $M_{rounded} = 8.00$, $SD = 1.08$ vs. $M_{angular} = 7.04$, $SD = 1.21$, $F(1, 116) = 8.87$, $p = .004$).

Figure a5

Study 3b: Taste Judgements as a Function of Product Shape and Visual Training Under No Load



Instruction and Stimuli

Visual Training—Visual Load—Angular/Rounded Shape

Dear participants,

Thank you so much for participating in our experiment. In this experiment, we will ask you to complete three tasks.

In the first task, you will view a series of food pictures and we want you to evaluate the tastes of the foods. BUT before you start evaluating, please first **visualize** the tastes of the foods shown in the pictures. For example, before you evaluate the taste of a watermelon, please first visually imagine how juicy the watermelon is, or a scene expressing your taste experience when you eat the watermelon.

In the second task, we will show you a 5 X 5 grid image with a symbol "X" in some of the cells. Please **visualize** this picture in your mind and remember the positions of the cells that have the symbol "X" in the table. And please try to keep this image in your mind continually until you complete the **third** task, because we will ask you to recreate the grid image at the end. In the third task, we will show you some food pictures again and we want you to answer a couple of simple questions based on your feelings of the foods. BUT at the same time, please do not forget to keep the grid image you memorized in the **second** task in your mind.

At the end of this experiment, we will ask you to recreate the table and point out which cells have a symbol "X."

Do not worry. At the beginning of each task, we will remind you of the instructions again.

Before starting the food evaluation task (Task 1), we would like you to answer a few questions about the way you typically evaluate the taste of food.

- To what extent will you *spontaneously* visualize the taste of a food after you see the food (e.g., visually imagine how juicy a watermelon is, or a scene expressing your taste experience when you eat the watermelon)? 1= not at all, 9 = very much
- To what extent will you *spontaneously* visualize the taste of a food when you evaluate the taste of the food? 1= not at all, 9 = very much
- To what extent do you rely on visualization when you evaluate the taste of a food? 1= not at all, 9 = very much

Welcome to task one!

In this task, you will view a series of food pictures and we want you to evaluate the tastes of the foods. BUT before you start evaluating, please first **visualize** the tastes of the foods shown in the pictures. For example, before you evaluate the taste of a watermelon, please first visually imagine how juicy the watermelon is, or a scene expressing your taste experience when you eat the watermelon.

(1) Please view the following *beer* picture and fully visualize the taste of the beer. Next, please rate the taste of the beer.

- How *carbonated* do you think the taste of the beer is? 1 = not at all carbonated, 9 = very carbonated
- How *bitter* do you think the taste of the beer is? 1 = not at all bitter, 9 = very bitter

(2) Please view the following *burger* picture and fully visualize the taste of the burger. Next, please rate the taste of the burger.

- How *salty* do you think the taste of the burger is? 1 = not at all salty, 9 = very salty
- How *sour* do you think the taste of the burger is? 1 = not at all sour, 9 = very sour

(3) Please view the following *cheese* picture and fully visualize the taste of the cheese. Next, please rate the taste of the cheese.

- How *smooth* do you think the taste of the cheese is? 1 = not at all smooth, 9 = very smooth
- How *creamy* do you think the taste of the cheese is? 1 = not at all creamy, 9 = very creamy

(4) Please view the following *cherry* picture and fully visualize the taste of the cherry. Next, please rate the taste of the cherry.

- How *sweet* do you think the taste of the cherry is? 1 = not at all sweet, 9 = very sweet
- How *sour* do you think the taste of the cherry is? 1 = not at all sour, 9 = very sour

(5) Please view the following *chips* picture and fully visualize the taste of the chips. Next, please rate the taste of the chips.

- How *salty* do you think the taste of the chips is? 1 = not at all salty, 9 = very salty
- How *crispy* do you think the taste of the chips is? 1 = not at all crispy, 9 = very crispy

(6) Please view the following *coke* picture and fully visualize the taste of the coke. Next, please rate the taste of the coke.

- How *sweet* do you think the taste of the coke is? 1 = not at all sweet, 9 = very sweet
- How *carbonated* do you think the taste of the coke is? 1 = not at all carbonated, 9 = very carbonated

(7) Please view the following *cookies* picture and fully visualize the taste of the cookies. Next, please rate the taste of the cookies.

- How *sweet* do you think the taste of the cookies is? 1 = not at all sweet, 9 = very sweet
- How *crispy* do you think the taste of the cookies is? 1 = not at all crispy, 9 = very crispy

(8) Please view the following *chocolate* picture and fully visualize the taste of the chocolate. Next, please rate the taste of the chocolate.

- How *bitter* do you think the taste of the chocolate is? 1 = not at all bitter, 9 = very bitter
- How *smooth* do you think the taste of the chocolate is? 1 = not at all smooth, 9 = very smooth

(9) Please view the following *coffee* picture and fully visualize the taste of the coffee. Next, please rate the taste of the coffee.

- How *bitter* do you think the taste of the coffee is? 1 = not at all bitter, 9 = very bitter
- How *sour* do you think the taste of the coffee is? 1 = not at all sour, 9 = very sour

(10) Please view the following *Fanta* picture and fully visualize the taste of the Fanta. Next, please rate the taste of the Fanta.

- How *carbonated* do you think the taste of the Fanta is? 1 = not at all carbonated, 9 = very carbonated
- How *sour* do you think the taste of the Fanta is? 1 = not at all sour, 9 = very sour

(11) Please view the following picture of *fried chicken* and fully visualize the taste of the fried chicken. Next, please rate the taste of the fried chicken.

- How *spicy* do you think the taste of the fried chicken is? 1 = not at all spicy, 9 = very spicy
- How *crispy* do you think the taste of the fried chicken is? 1 = not at all crispy, 9 = very crispy

(12) Please view the following picture of a *shrimp dish* and fully visualize the taste of the shrimp dish. Next, please rate the taste of the shrimp dish.

- How *spicy* do you think the taste of the shrimp dish is? 1 = not at all spicy, 9 = very spicy
- How *salty* do you think the taste of shrimp dish is? 1 = not at all salty, 9 = very salty

(13) Please view the following *grapefruit* picture and fully visualize the taste of the grapefruit. Next, please rate the taste of the grapefruit.

- How *sour* do you think the taste of the grapefruit is? 1 = not at all sour, 9 = very sour
- How *bitter* do you think the taste of the grapefruit is? 1 = not at all bitter, 9 = very bitter

(14) Please view the following *grapes* picture and fully visualize the taste of the grapes. Next, please rate the taste of the grapes.

- How *sour* do you think the taste of the grapes is? 1 = not at all sour, 9 = very sour
- How *sweet* do you think the taste of the grapes is? 1 = not at all sweet, 9 = very sweet

(15) Please view the following *tea* picture and fully visualize the taste of the tea. Next, please rate the taste of the tea.

- How *sour* do you think the taste of the tea is? 1 = not at all sour, 9 = very sour
- How *bitter* do you think the taste of the tea is? 1 = not at all bitter, 9 = very bitter

(16) Please view the following *ice-cream* picture and fully visualize the taste of the ice-cream. Next, please rate the taste of the ice-cream.

- How *smooth* do you think the taste of the ice-cream is? 1 = not at all smooth, 9 = very smooth
- How *creamy* do you think the taste of the ice-cream is? 1 = not at all creamy, 9 = very creamy

(17) Please view the following *coffee* picture and fully visualize the taste of the coffee. Next, please rate the taste of the coffee.

- How *smooth* do you think the taste of the coffee is? 1 = not at all smooth, 9 = very smooth
- How *creamy* do you think the taste of the coffee is? 1 = not at all creamy, 9 = very creamy

(18) Please view the following *lemon* picture and fully visualize the taste of the lemon. Next, please rate the taste of the lemon.

- How *bitter* do you think the taste of the lemon is? 1 = not at all bitter, 9 = very bitter
- How *sour* do you think the taste of the lemon is? 1 = not at all sour, 9 = very sour

(19) Please view the following *milk* picture and fully visualize the taste of the milk. Next, please rate the taste of the milk.

- How *creamy* do you think the taste of the milk is? 1 = not at all creamy, 9 = very creamy
- How *smooth* do you think the taste of the milk is? 1 = not at all smooth, 9 = very smooth

(20) Please view the following *pasta* picture and fully visualize the taste of the pasta. Next, please rate the taste of the pasta.

- How *creamy* do you think the taste of the pasta is? 1 = not at all creamy, 9 = very creamy
- How *salty* do you think the taste of the pasta is? 1 = not at all salty, 9 = very salty

(21) Please view the following *pineapple* picture and fully visualize the taste of the pineapple. Next, please rate the taste of the pineapple.

- How *sweet* do you think the taste of the pineapple is? 1 = not at all sweet, 9 = very sweet
- How *sour* do you think the taste of the pineapple is? 1 = not at all sour, 9 = very sour

(22) Please view the following *pizza* picture and fully visualize the taste of the pizza. Next, please rate the taste of the pizza.

- How *salty* do you think the taste of the pizza is? 1 = not at all salty, 9 = very salty
- How *spicy* do you think the taste of the pizza is? 1 = not at all spicy, 9 = very spicy

(23) Please view the following *salmon* picture and fully visualize the taste of the salmon. Next, please rate the taste of the salmon.

- How *sweet* do you think the taste of the salmon is? 1 = not at all sweet, 9 = very sweet
- How *smooth* do you think the taste of the salmon is? 1 = not at all smooth, 9 = very smooth

(24) Please view the following *sandwich* picture and fully visualize the taste of the sandwich. Next, please rate the taste of the sandwich.

- How *salty* do you think the taste of the sandwich is? 1 = not at all salty, 9 = very salty
- How *sour* do you think the taste of the sandwich is? 1 = not at all sour, 9 = very sour

(25) Please view the following picture of *sparkling water* and fully visualize the taste of the sparkling water. Next, please rate the taste of the sparkling water.

- How *smooth* do you think the taste of the sparkling water is? 1 = not at all smooth, 9 = very smooth
- How *carbonated* do you think the taste of the sparkling water is? 1 = not at all carbonated, 9 = very carbonated

(26) Please view the following picture of a *chicken dish* and fully visualize the taste of the chicken dish. Next, please rate the taste of the chicken dish.

- How *salty* do you think the taste of the chicken dish is? 1 = not at all salty, 9 = very salty
- How *spicy* do you think the taste of the chicken dish is? 1 = not at all spicy, 9 = very spicy

(27) Please view the following picture of *still water* and fully visualize the taste of the still water. Next, please rate the taste of the still water.

- How *smooth* do you think the taste of the still water is? 1 = not at all smooth, 9 = very smooth

- How *carbonated* do you think the taste of the still water is? 1 = not at all carbonated, 9 = very carbonated

(28) Please view the following *strawberry* picture and fully visualize the taste of the strawberry. Next, please rate the taste of the strawberry.

- How *sweet* do you think the taste of the strawberry is? 1 = not at all sweet, 9 = very sweet
- How *sour* do you think the taste of the strawberry is? 1 = not at all sour, 9 = very sour

(29) Please view the following *chocolate* picture and fully visualize the taste of the chocolate. Next, please rate the taste of the chocolate.

- How *sweet* do you think the taste of the chocolate is? 1 = not at all sweet, 9 = very sweet
- How *creamy* do you think the taste of the chocolate is? 1 = not at all creamy, 9 = very creamy

(30) Please view the following *wine* picture and fully visualize the taste of the wine. Next, please rate the taste of the wine.

- How *bitter* do you think the taste of the wine is? 1 = not at all bitter, 9 = very bitter
- How *smooth* do you think the taste of the wine is? 1 = not at all smooth, 9 = very smooth

- Overall, how difficult do you think the evaluation task of food taste is? 1 = not at all difficult, 9 = very difficult

- Overall, how much effort did you put into the evaluation task of food taste? 1 = no effort, 9 = very much effort

In Task 1, you have evaluated the tastes of a series of foods under our instruction. Now, we would like to understand whether the evaluation tasks influence the way you evaluate the taste of food. Please answer the following questions.
- Now, to what extent will you *spontaneously* visualize the taste of a food after you see the food (e.g., visually imagine how juicy a watermelon is, or a scene expressing your taste experience when you eat the watermelon)? 1= not at all, 9 = very much
- Now, to what extent will you *spontaneously* visualize the taste of a food when you evaluate the taste of the food? 1= not at all, 9 = very much
- Now, to what extent do you rely on visualization when you evaluate the taste of a food? 1= not at all, 9 = very much

Congratulations! You have completed task one! Welcome to tasks two and three!

In the second task, we will show you a 5 X 5 grid image with a symbol "X" in some of the cells. Please visualize this picture in your mind and remember the positions of the cells that have the symbol "X" in the table. And please try to keep this image in your mind continually until you complete the **third** task, because we will ask you to recreate the grid image at the end. In the third task, we will show you some food pictures again and we want you to answer a couple of simple questions based on your feelings of the foods. BUT at the same time, please do NOT forget to keep the grid image you memorized in the **second** task in your mind.
At the end of this experiment, we will ask you to recreate the table and point out which cells have a symbol "X."

Welcome to task two!

Please carefully view the following 5 X 5 grid image and try to visualize it in your mind and remember the positions of the cells that have the symbol "X" in the table. Please do NOT take notes on paper in order to memorize this table. When you feel that you have remembered this image, please enter in the third task. Meanwhile, please try to keep this image in your mind continually until you complete the **third** task, because we will ask you to recreate the grid image at the end.

		X		
	X			**X**
		X	**X**	
X	**X**		**X**	
		X		**X**

Welcome to task three!

In this task, we want you to know your initial reactions to some foods and drinks.

(1) Please carefully view the picture below of a *sparkling water* and then answer a few questions about it.

- How *carbonated* do you think the sparkling water is? 1 = not at all carbonated, 9 = very carbonated
- How *smooth* do you think the sparkling water is? 1 = not at all smooth, 9 = very smooth

(2) Please carefully view the picture below of a *chocolate bar* and then answer a few questions about it.

- How *sweet* do you think the chocolate bar is? 1 = not at all sweet, 9 = very sweet
- How *bitter* do you think the chocolate bar is? 1 = not at all bitter, 9 = very bitter

- Please indicate which cells have the symbol "X" in the following matrix (each point represents a cell):

- What is your gender? □ Female □ Male
- How old are you? ______________________

No Training—Visual Load—Angular/Rounded Shape

Dear participants,

Thank you so much for participating in our experiment. In this experiment, we will ask you to complete three tasks.

In the first task, you will see a series of calculation problems and we want you to evaluate the difficulty of the questions.

In the second task, we will show you a 5 X 5 grid image with a symbol "X" in some of the cells. Please **visualize** this picture in your mind and remember the positions of the cells that have the symbol "X" in the table. And please try to keep this image in your mind continually until you complete the **third** task, because we will ask you to recreate the grid image at the end.

In the third task, we will show you some food pictures and we want you to answer a couple of simple questions based on your feelings of the foods. BUT at the same time, please do not forget to keep the grid image you memorized in the **second** task in your mind.

At the end of this experiment, we will ask you to recreate the table and point out which cells have a symbol "X."

<u>Do not worry. At the beginning of each task, we will remind you of the instructions again.</u>

Before starting the food evaluation task (Task 1), we would like you to answer a few questions about the way you typically evaluate the taste of food.
- To what extent will you *spontaneously* visualize the taste of a food after you see the food (e.g., visually imagine how juicy a watermelon is, or a scene expressing your taste experience when you eat the watermelon)? 1= not at all, 9 = very much
- To what extent will you *spontaneously* visualize the taste of a food when you evaluate the taste of the food? 1= not at all, 9 = very much
- To what extent do you rely on visualization when you evaluate the taste of a food? 1= not at all, 9 = very much

Welcome to task one!

In this task, you will see a series of calculation problems and we want you to evaluate the difficulty of the questions. Note that we do NOT need you to give answers for the calculation problems, but we hope you try to calculate them a bit and give an objective evaluation for the difficulty of each question.

Please evaluate the difficulty of the following calculation problem:

1) 10+645+90

2) 10×6×9
3) 10×8+572
4) 888÷4-2
5) 34÷17÷1
6) 105×8÷4
7) 18-2.7-9.3
8) 7.5-0.26-1.74+2.5
9) 23.5-2.8-7.2
10) 58.65-(3.2+8.65)
11) 0.134+2.66+0.866
12) 7.5+4.9-6.5
13) 3.07-0.38-1.62
14) 1.29+3.7+2.71+6.3
15) 8-2.45-1.55
16) 14-7.32-2.68
17) 2.64+8.67+7.36+11.33
18) 20-8×2÷4
19) 420×(13+57)×90
20) 66×38-987÷21
21) 196÷4+56×12
22) 16×50-36÷4
23) (73+65)÷(210-164)
24) (1024+4370)÷(24+38)
25) 95÷(64-45)
26) 347+45×2-4160÷52
27) (58+37)÷(64-9×5)
28) 120-36×4÷18+35
29) 0.25×13×4
30) 32×0.125

- How difficult do you think this calculation problem is? 1 = not at all difficult, 9 = very difficult
- How much effort do you need to pay if you solve this calculation problem? 1 = no effort, 9 = very much effort

- Overall, how difficult do you think the evaluation task of calculation problem is? 1 = not at all difficult, 9 = very difficult
- Overall, how much effort did you put into the evaluation task of calculation problem? 1 = no effort, 9 = very much effort

Now, we would like you to answer a few questions about the way you typically evaluate the taste of food again.
- Now, to what extent will you *spontaneously* visualize the taste of a food after you see the food (e.g., visually imagine how juicy a watermelon is, or a scene expressing your taste experience when you eat the watermelon)? 1= not at all, 9 = very much
- Now, to what extent will you *spontaneously* visualize the taste of a food when you evaluate the taste of the food? 1= not at all, 9 = very much

- Now, to what extent do you rely on visualization when you evaluate the taste of a food? 1= not at all, 9 = very much

Congratulations! You have completed task one! Welcome to tasks two and three!

In the second task, we will show you a 5 X 5 grid image with a symbol “X” in some of the cells. Please visualize this picture in your mind and remember the positions of the cells that have the symbol “X” in the table. And please try to keep this image in your mind continually until you complete the **third** task, because we will ask you to recreate the grid image at the end.

In the third task, we will show you some food pictures and we want you to answer a couple of simple questions based on your feelings of the foods. BUT at the same time, please do NOT forget to keep the grid image you memorized in the **second** task in your mind.

At the end of this experiment, we will ask you to recreate the table and point out which cells have a symbol “X.”

Welcome to task two!

Please carefully view the following 5 X 5 grid image and try to visualize it in your mind and remember the positions of the cells that have the symbol “X” in the table. Please do NOT take notes on paper in order to memorize this table. When you feel that you have remembered this image, please enter in the third task. Meanwhile, please try to keep this image in your mind continually until you complete the **third** task, because we will ask you to recreate the grid image at the end.

		X		
	X			**X**
		X	**X**	
X	**X**		**X**	
		X		**X**

Welcome to task three!

In this task, we want you to know your initial reactions to some foods and drinks.

(1) Please carefully view the picture below of a *sparkling water* and then answer a few questions about it.

- How *carbonated* do you think the sparkling water is? 1 = not at all carbonated, 9 = very carbonated
- How *smooth* do you think the sparkling water is? 1 = not at all smooth, 9 = very smooth

(2) Please carefully view the picture below of a *chocolate bar* and then answer a few questions about it.

- How *sweet* do you think the chocolate bar is? 1 = not at all sweet, 9 = very sweet
- How *bitter* do you think the chocolate bar is? 1 = not at all bitter, 9 = very bitter

- Please indicate which cells have the symbol "X" in the following matrix (each point represents a cell):

- What is your gender? □ Female □ Male
- How old are you? ____________________

Visual Training—No load—Angular/Rounded Shape

Dear participants,

Thank you so much for participating in our experiment. In this experiment, we will ask you to complete two tasks.

In the first task, you will view a series of food pictures and we want you to evaluate the tastes of the foods. BUT before you start evaluating, please first **visualize** the tastes of the foods shown in the pictures. For example, before you evaluate the taste of a watermelon, please first visually imagine how juicy the watermelon is, or a scene expressing your taste experience when you eat the watermelon.

In the second task, we will show you some food pictures again and we want you to answer a couple of simple questions based on your feelings of the foods.

Before starting the food evaluation task (Task 1), we would like you to answer a few questions about the way you typically evaluate the taste of food.

- To what extent will you *spontaneously* visualize the taste of a food after you see the food (e.g., visually imagine how juicy a watermelon is, or a scene expressing your taste experience when you eat the watermelon)? 1= not at all, 9 = very much
- To what extent will you *spontaneously* visualize the taste of a food when you evaluate the taste of the food? 1= not at all, 9 = very much
- To what extent do you rely on visualization when you evaluate the taste of a food? 1= not at all, 9 = very much

Welcome to task one!

In this task, you will view a series of food pictures and we want you to evaluate the tastes of the foods. BUT before you start evaluating, please first **visualize** the tastes of the foods shown in the pictures. For example, before you evaluate the taste of a watermelon, please first visually imagine how juicy the watermelon is, or a scene expressing your taste experience when you eat the watermelon.

[The stimuli are the same as those shown above in the condition of Visual Training]

- Overall, how difficult do you think the evaluation task of food taste is? 1 = not at all difficult, 9 = very difficult
- Overall, how much effort did you put into the evaluation task of food taste? 1 = no effort, 9 = very much effort

In Task 1, you have evaluated the tastes of a series of foods under our instruction. Now, we would like to understand whether the evaluation tasks influence the way you evaluate the taste of food. Please answer the following questions.

- Now, to what extent will you *spontaneously* visualize the taste of a food after you see the food (e.g., visually imagine how juicy a watermelon is, or a scene expressing your taste experience when you eat the watermelon)? 1= not at all, 9 = very much
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- Now, to what extent do you rely on visualization when you evaluate the taste of a food? 1= not at all, 9 = very much

Welcome to task two!

In this task, we want you to know your initial reactions to some foods and drinks.

(1) Please carefully view the picture below of a *sparkling water* and then answer a few questions about it.


- How *carbonated* do you think the sparkling water is? 1 = not at all carbonated, 9 = very carbonated
- How *smooth* do you think the sparkling water is? 1 = not at all smooth, 9 = very smooth

(2) Please carefully view the picture below of a *chocolate bar* and then answer a few questions about it.

- How *sweet* do you think the chocolate bar is? 1 = not at all sweet, 9 = very sweet
- How *bitter* do you think the chocolate bar is? 1 = not at all bitter, 9 = very bitter

- What is your gender? □ Female □ Male
- How old are you? ______________________

No Training—No Load—Angular/Rounded Shape

Dear participants,

Thank you so much for participating in our experiment. In this experiment, we will ask you to complete two tasks.

In the first task, you will see a series of calculation problems and we want you to evaluate the difficulty of the questions.

In the second task, we will show you some food pictures and we want you to answer a couple of simple questions based on your feelings of the foods.

Before starting the food evaluation task (Task 1), we would like you to answer a few questions about the way you typically evaluate the taste of food.
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Welcome to task one!

In this task, you will see a series of calculation problems and we want you to evaluate the difficulty of the questions. Note that we do NOT need you to give answers for the calculation problems, but we hope you try to calculate them a bit and give an objective evaluation for the difficulty of each question.

[The stimuli are the same as those shown above in the condition of No Training]

- Overall, how difficult do you think the evaluation task of calculation problem is? 1 = not at all difficult, 9 = very difficult
- Overall, how much effort did you put into the evaluation task of calculation problem? 1 = no effort, 9 = very much effort

Now, we would like you to answer a few questions about the way you typically evaluate the taste of food again.
- Now, to what extent will you *spontaneously* visualize the taste of a food after you see the food (e.g., visually imagine how juicy a watermelon is, or a scene expressing your taste experience when you eat the watermelon)? 1= not at all, 9 = very much
- Now, to what extent will you *spontaneously* visualize the taste of a food when you evaluate the taste of the food? 1= not at all, 9 = very much

- Now, to what extent do you rely on visualization when you evaluate the taste of a food? 1= not at all, 9 = very much

Welcome to task two!

In this task, we want you to know your initial reactions to some foods and drinks.

(1) Please carefully view the picture below of a *sparkling water* and then answer a few questions about it.


- How *carbonated* do you think the sparkling water is? 1 = not at all carbonated, 9 = very carbonated
- How *smooth* do you think the sparkling water is? 1 = not at all smooth, 9 = very smooth

(2) Please carefully view the picture below of a *chocolate bar* and then answer a few questions about it.

- How *sweet* do you think the chocolate bar is? 1 = not at all sweet, 9 = very sweet
- How *bitter* do you think the chocolate bar is? 1 = not at all bitter, 9 = very bitter

- What is your gender? □ Female □ Male
- How old are you? ______________________