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Combining Typeface and Color to Prime Specific Taste Expectations

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The effects of color and typeface on people's taste expectations have been well documented in the literature on crossmodal correspondences. However, research on the interaction between different visual features when they are collectively associated with specific taste qualities is scarce. Here, an online study is presented that examines the combined effect of color and typeface by simultaneously manipulating the color scheme and font curvilinearity of text stimuli. The findings confirm the main effects of color hue and typeface curvilinearity in terms of modulating the strength of association with the four basic taste qualities (sweet, sour, salty, and bitter). The results revealed that the congruent pairings of color hue and typeface curvilinearity induced stronger taste associations. In particular, the combinations of congruent visual text properties further modified the strength of taste association with sweet ($p < .005$), sour ($p < .0001$), bitter ($p < .001$), and with a borderline-significant effect in the case of salty ($p = .054$). There was no effect of typeface curvilinearity on sour ratings when the text stimuli were presented in colors that had previously been documented to associate with sourness. Overall, the effects of color and typeface on taste expectations induced by text stimuli follow the documented patterns of hue–taste and curvilinearity–taste correspondences. Although both color and typeface exerted a significant effect on taste expectations, the evidence presented here suggests that the color scheme tends to dominate over typeface curvilinearity when determining the taste quality that people associate with a given text stimulus.

Keywords: crossmodal correspondences, taste, typeface, curvilinearity, color

By using the documented patterns of crossmodal correspondences between vision and taste (such as sweet being associated with pink and red) in product packaging and visual presentation of food and drinks, research shows that specific visual features can alter people's taste expectations, and sometimes also their taste and flavor experiences (Velasco, Hyndman, & Spence, 2018; Velasco, Michel, et al., 2016; see B. P. Lee & Spence, 2022; Spence et al., 2015). Thus far, visual features such as color hue (Spence, 2019), curvilinearity (Velasco, Woods, et al., 2016), symmetry (Turoman et al., 2018), and other nonverbal visual cues (e.g., visual texture; Barbosa Escobar et al., 2022) have been shown to give rise to specific taste expectations. In recent years, research on the crossmodal correspondences—a term used to describe such associations between features from different sensory modalities—has demonstrated that visual features can be drawn from various contexts to shape impressions concerning taste (Motoki & Velasco, 2021). These visual cues may be found in product packaging (Velasco, Michel, et al., 2016), food containers (Sugimori & Kawasaki, 2022; Van Doorn et al., 2017; Wan et al., 2016), food appearance (F. R. Carvalho et al., 2017; Q. J. Wang et al., 2017), font characteristics (Velasco et al., 2014), ambient environment (Spence, 2018; Spence et al., 2014; Wu et al., 2022), and even in abstract elements when displayed in isolation (Velasco, Michel, et al., 2016; Wan et al., 2014).

While research has shown that the way visual features are arranged can affect both purchasing decisions and taste perception (Barnett & Spence, 2016; Sousa et al., 2020; Sugimori & Kawasaki, 2022), some unexpected influences on people's taste appraisals have been reported when visual stimuli have incorporated, or combined, multiple graphic elements (Rolschau et al., 2020; Stewart & Goss, 2013). These unexpected effects suggest, for example, that combining different visual features might not result in a simple summation of the strength of taste associations (see B. P. Lee & Spence, 2023; Woods et al., 2016). To bring applications of crossmodal correspondences research closer to real life, marketing practitioners and researchers alike are now attempting to understand how complex images that incorporate multiple visual features may guide taste expectations (Gil-Pérez et al., 2019; J. Lee & Lim, 2022; Michel et al., 2014; Petit et al., 2019). It is, though, important to recognize how the underlying mechanisms of vision–taste correspondences may differ depending on the visual feature involved; for example, it has been suggested that color–taste correspondences arise primarily from the internalization of statistics in the environment (i.e., objects and concepts that are frequently experienced together and correlated accordingly; Schloss et al., 2018; Spence & Levitan, 2021), whereas shape–taste correspondences seem to be mediated by the emotions associated, respectively, with shapes and tastes (i.e., believed to emerge from the grouping of experiences that possess a similar hedonic value, or tone; Spence, 2022b; Velasco, Woods, Deroy, & Spence, 2015). Despite the importance of understanding the

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interaction between these visual features, relatively little attention has been given over to the combination of visual features in vision–taste correspondences, especially those assumed to be from different origins, such as color and geometric properties. The study reported here was designed to examine the interaction between visual features applied to the font by inviting observers to identify taste associations of text stimuli in assorted coloring schemes and typefaces of different curvilinearity.

There is currently ample peer-reviewed empirical research demonstrating that people consensually associate specific taste qualities with particular color hues (Spence et al., 2015) and with typeface curvilinearity (Velasco, Woods, Hyndman, & Spence, 2015). In this context, the idea is that the basic tastes most commonly examined in the literature—namely, sweet, sour, salty, bitter, and umami (generally identified as the "five basic qualities"; see Beauchamp, 2019)—would correspond to a specific color or curvilinearity feature (and vice versa). Although there may be some variations in associations across cultures (Bremner et al., 2013; Machiels & Orth, 2019; Wan et al., 2014) and groups of individuals (Otterbring et al., 2022; Shankar et al., 2010; Spence, 2022a), a high degree of consistency has been observed in the crossmodal matching studies (Chen et al., 2018; Spence, 2019). Table 1 presents the respective studies on the taste correspondences of color hue and typeface curvilinearity, and the matching visual features for each taste quality are illustrated in Figure 1. The associations reported by different studies appear to agree as concerns how sensory attributes are matched between taste and vision; however, the evidence also highlights the distinct contrast in mapping patterns between color hues and curvilinearity features. While taste qualities are associated with a diverse range of color hues, curvilinearity features are simply divided by "sweet-tasting" roundedness and "non-sweet-tasting" angularity. This could be indicative of how people rely on or directed by different mechanisms to associate taste with color hues and with curvilinearity features.

Another key visual feature in the present investigation is typeface curvilinearity. Its matching patterns with taste qualities are largely derived from the framework of crossmodal associations between shape curvilinearity and taste quality (e.g., Ngo et al., 2012; see Velasco & Spence, 2019; Velasco, Hyndman, & Spence, 2018). Indeed, typeface curvilinearity has been demonstrated to prime people's taste expectations and perceptions. Velasco et al. (2014) placed either rounded or angular typeface (see Figure 1) on product packages and had their participants rate the expected intensity of sweetness and sourness of the products. Packages featuring rounded typefaces were associated with a sweeter taste and angular with a taste that was sourer. Sousa et al. (2020) showed that featuring text in angular typeface on the product label increased assessors' acidity rating of the coffee compared to the rounded typeface (see Figure 2). The effect was observed for both expectations upon viewing the package and the actual perception after tasting the coffee. Remarkably, Sousa et al. found no association between rounded typefaces and sweet expectations or perceptions. This could imply that taste expectations based on color cues, like the lack of sweetness of black coffee, might override or block the shape–taste correspondences when these visual cues are presented together (Cardello & Sawyer, 1992; F. M. Carvalho & Spence, 2019).

What sensory qualities a given typeface might prime in the mind of an observer is not defined solely by its curvilinearity characteristics (Henderson et al., 2004; McCarthy & Mothersbaugh, 2002). The evaluation of typeface involves a unique system of typesetting (e.g., spacing, kerning, leading, hanging, tracking, etc.) and aesthetic appraisal (e.g., serif, slab, orientation, stem, weight, obliqueness) that are not seen in other geometric features—assuming, that is, typeface can be regarded as a form of geometric feature (Keage et al., 2014; Kuvykaite et al., 2009). Some typeface families (i.e., a group of typefaces sharing the same design language; see Zeng et al., 2019) have also been found to prime semantic meanings and personalities (Celhay et al., 2015; Johannessen et al., 2021; van Leeuwen, 2006). Nevertheless, despite the diverse psychological effects of typeface, its taste profile is most notably determined by the degree of font curvilinearity among the other typeface attributes that have been investigated to date (Velasco, Hyndman, & Spence, 2018).

Most of the studies that have been published to date have been designed to examine the taste correspondence associated with a single visual feature (e.g., color or shape properties presented in isolation), while features from other visual dimensions were kept constant. In this context, "visual dimension" refers to our approach to distinguish between color hue, shape curvilinearity, texture, and other types of visual features characterized by having distinct patterns of vision–taste correspondences. Admittedly, a few studies have investigated the interactions between visual features within the same dimension, using paradigms such as presenting multiple color hues simultaneously (Woods & Spence, 2016; Woods et al., 2016) or comparing the taste associations of shapes with varying degrees of curvilinearity and symmetry (Salgado-Montejo et al., 2015). Despite these efforts, few studies have examined the taste associations of stimuli where several visual features (i.e., features from different visual dimensions) are manipulated simultaneously (B. P. Lee & Spence, 2023).

When the vision–taste correspondences are put to test in real life, there have been reports of unanticipated effects presumably due to

Table 1

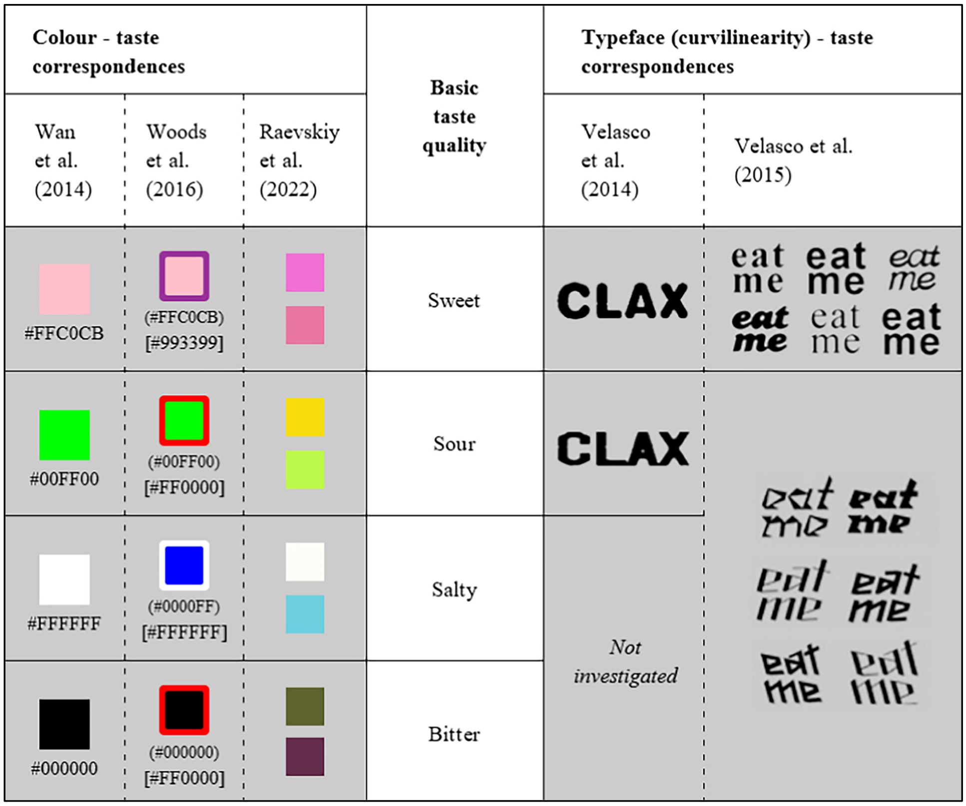
Color or Typeface Curvilinearity (or Combinations Thereof) Most Strongly Associated With Each of the Four Basic Tastes

Study	Visual stimuli involved	Taste quality: Sweet	Sour	Salty	Bitter
Wan et al. (2014)	Single-color patch	Pink	Green	White	Black
Woods et al. (2016)	Bicolor patch	Pink-on-purple	Green-on-red	White-on-blue	Black-on-white
Raevskiy et al. (2022)	Single-color patch	Pink Light red	Yellow Green	White Blue	Dark green Brown
Velasco et al. (2014)	Typeface curvilinearity	Rounded	Angular		
Velasco, Woods, Hyndman, & Spence (2015)	Typeface curvilinearity	Rounded	Angular	Angular	Angular

Note. These matches were established by surveying taste expectations of the visual features or vice versa.

Figure 1

The Colors and Typeface Examples Best Matched With the Four Basic Tastes in Previous Research



Note. In the studies of Wan et al. (2014) and Woods et al. (2016), web-safe colors were used to prepare the stimuli. The hex codes are annotated in this figure, codes in rounded and square brackets, respectively, represent the hex code of foreground and background color used in Woods et al.'s study. Raevskiy et al. (2022) used a customized color panel for their color stimuli; the color patches presented here are extracted from their digitally published figure to preserve color accuracy. See the online article for the color version of this figure.

the interaction of visual features. For example, Rolschau et al. (2020) conducted a field study in a bar to assess the influence of typeface curvilinearity on beer purchase behavior. Rolschau and colleagues found that the two typeface styles (vary in curvilinearity, weight, and filling) used on the menu to have an effect on the amount purchased and preference for the beer's taste/flavor (see Figure 3). However, the menu with a rounded typeface style led to more sour-tasting beer being purchased, which was surprising given that the rounded typeface on product packages is generally found to associate with the expectation of sweetness (Sousa et al., 2020; Velasco, Woods, Hyndman, & Spence, 2015). Considering the prospect of interactions occurring between visual features in crossmodal correspondences research, it is worth entertaining the idea that certain coloring schemes (that were applied to the menu items) might have rendered the effect of typeface less robust in Rolschau et al.'s field study.

One might understandably question whether color cues and typeface curvilinearity are compatible in terms of their ability to prime taste expectations. This concern thus warrants a brief discussion on the principles that motivate or guide people to make the associations documented between visual features and taste qualities. Recent reviews on the origins of crossmodal correspondences between visual features and taste qualities suggest that people appear to rely on the experiences and beliefs acquired from the general environment to decide on color–taste associations (Barlow, 2001; Spence, 2022a; Spence & Levitan, 2021), while drawing reference from the valence value of shape properties and taste qualities to accordingly match the associations between curvilinearity and taste (Schifferstein & Tanudjaja, 2004; Spence, 2022b, 2023; Q. J. Wang et al., 2016). Notwithstanding the existence of valence associated with color hues (Adams & Osgood, 1973; Elliot, 2019), people tend to prioritize the internalized statistics of the environment in forming the color–taste associations (i.e., when there is access to a source object/concept; Spence & Levitan, 2021). This implies a cognitive system for managing different principles when people are asked to make crossmodal associations, with a preference for internalized statistics over emotional mediation—at least when matching color hues with taste qualities (Schifferstein & Tanudjaja, 2004). Although previous research has demonstrated the additive interaction between different visual features that follow the same principle for building taste correspondences (e.g., shape curvilinearity and symmetry; Salgado-Montejo et al., 2015), little is known about how the two principles would interact when the assessors are forced to access both internalized statistics and mediating emotions to make crossmodal matching decisions (B. P. Lee & Spence, 2023). A paradigm that manipulates both

Figure 2

Stimuli Used in Sousa et al.'s (2020) Study to Compare the Influence on Taste Expectation/Perception by Rounded (Left) and Angular (Right) Typeface on the Package

Note. Adapted from "Do Typefaces of Packaging Labels Influence Consumers' Perception of Specialty Coffee? A Preliminary Study," by M. M. M. Sousa, F. M. Carvalho, and R. G. F. A. Pereira, 2020, *Journal of Sensory Studies, 35*(5), Article e12599 (https://doi.org/10.1111/joss.12599). Copyright 1999–2023 by John Wiley & Sons. Adapted with permission. See the online article for the color version of this figure.

color and curvilinearity in the stimuli is essential to examining the priming effects of visual features driven by different principles.

Beyond the compatibility of visual cues in collectively priming taste expectations, the holistic processing of visual features would be another critical criterion to consider when examining the synergetic effects as a result of putative Gestalt experience (Grossberg, 1984; Köhler, 1929). In Woods et al.'s (2016) study on vision–taste crossmodal correspondences involving patches consisting of a pair of colors, some patches without a second color outline were used as a baseline to contrast the effect of bicolored stimuli. A notable example of this approach, as highlighted by Woods et al., was the synergy identified when placing a green patch inside a yellow outline, which displayed a stronger association with sourness than either the green or yellow single-colored patches with no outline. Furthermore, Woods and colleagues measured the reaction times (RTs) for participants to make taste correspondences for each stimulus, revealing that incorporating two colors into a patch as foreground–background schemes resulted in the same RTs as single-colored patches. This finding is

Figure 3

The Two Typeface Styles, Drawn in Different Colors, Weights, and Filling Methods, as Seen on the Beer Menu Displayed in Rolschau et al.'s (2020) Study

Note. Adapted from "Seeing Sweet and Choosing Sour: Compensatory Effects of Typeface on Consumers' Choice Behavior," by K. Rolschau, Q. J. Wang, and T. Otterbring, 2020, *Food Quality and Preference, 85*, Article 103964. CC BY 4.0. The menu items were the beer brands available on the day of their field study. When a brand sold out, the item was replaced on the menu with another brand of a similar taste profile. See the online article for the color version of this figure.

especially relevant when contrasted with a previous study on color–taste matching involving multiple colors by Woods and Spence (2016), where it was found that presenting two independent color patches side-by-side took significantly longer for participants to make a matching decision than their single-color counterparts.

The present study is designed to assess how the color profile and typeface curvilinearity of text stimuli would cooperate or compete as they are collectively associated with, if not conveying, information concerning taste quality. With a wealth of experimental evidence now documenting the taste mappings associated with color and typeface (Velasco, Woods, Hyndman, & Spence, 2015; Velasco, Hyndman, & Spence, 2018; Woods & Spence, 2016; Woods et al., 2016), it would seem reasonable to assume a greater strength of associations when the color profile is congruent with typeface curvilinearity in terms of their respective taste correspondences. For example, people should find texts rendered in a rounded typeface in a red-pink color to be sweeter than a rounded, green-yellow text or an angular, red-pink text. Given the findings reported by Rolschau et al. (2020), it is also anticipated that certain combinations of color and typeface might not necessarily result in synergy effects in their collective association with taste qualities.

Method

Participants

Overall, 107 native English speakers took part in the online study. The size of recruitment is consistent with the sample sizes used in previous similar vision–taste matching studies (e.g., Salgado-Montejo et al., 2015; Velasco et al., 2014; Woods et al., 2016). The participants were all born and living in the United Kingdom at the time of recruitment. All of the participants had normal or corrected-to-normal vision. Five participants failed to pass the attention check questions and had their data excluded from the final analysis. The final data consist of 102 participants (51 female, 51 male), aged between 19 and 90 years ($M = 41.7$, $SD = 16.0$). The experiment was reviewed and approved by the Medical Sciences Inter-Divisional Research Ethics Committee (IDREC) at the University of Oxford (reference number: R69143/RE002).

Apparatus and Materials

The experiment was programmed and conducted on the Qualtrics XM platform (https://qualtrics.com/), participants were recruited on Prolific (https://prolific.co/) and subsequently directed to Qualtrics to complete the tasks. The participants were required to complete the study using an up-to-date browser on any desktop system (including laptop).

Prior studies on crossmodal matching have shown that displaying pairs of colors simultaneously, each of which independently sets the same taste expectations (i.e., colors that are strongly associated with the same taste quality), resulted in a more robust association than when presenting the composite colors separately (Woods et al., 2016; Woods & Spence, 2016). In addition to demonstrating the synergistic prospect of feature interaction (albeit from the same visual dimension) in vision–taste associations, Woods et al.'s results provide a ranking list of color combinations (as foreground–background color schemes) associated with each of the four most common basic taste qualities (sweet, sour, salty, and bitter). The strength of the association between a color scheme and a taste quality was measured by their frequency of being selected as a matching pair. Among the combinations of colors tested by Woods et al., the top five most-associated color patches for each basic quality were applied as body–outline coloring schemes to the test stimuli in the current study, making a total of 20 coloring schemes (see Figure 4). Some of the patches selected consist of only a foreground color with no background; these conditions were displayed as colored text with no outline and slightly larger font size to make up the smaller size compared to the outlined stimuli.

The colors featured on the stimuli were prepared using the same *web-safe* color swatches as used in previous research (Woods et al., 2016; Woods & Spence, 2016). The hex codes were modified slightly to ensure compatibility across different browsers/monitors: #0F0, #FF0, #F00, #FCC,[1] #939, #00F, #FFF, #000 for green, yellow, red, pink, purple, blue, white, and black, respectively. All of the stimuli were displayed against a gray background (#888) throughout the study to maintain the visibility of the stimuli regardless of the brightness/lightness (Saito et al., 2005).

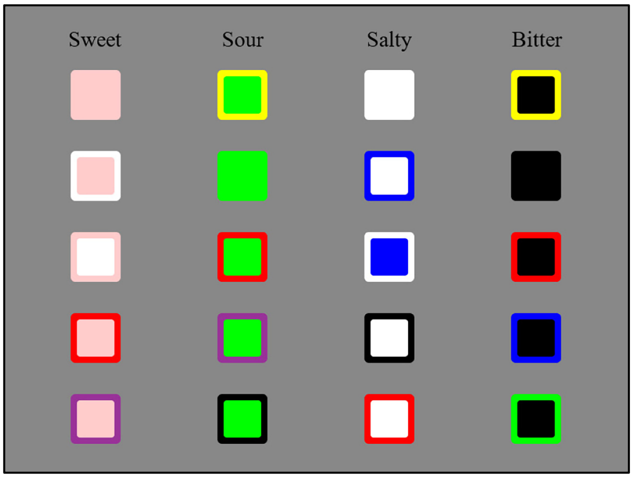
Back in the study of color patches by Woods and Spence (2016), the researchers considered longer RTs as a possible indication that their participants were processing the color pairs serially rather than as a unified stimulus. In the present study, the inclusion of coloring schemes without outlines enabled a similar exploration of the synergy effects between texts with multiple colors and those with only a single color. The setup also provides an opportunity to understand how taste associations for complex stimuli affect RTs.

In the majority of the previous research on crossmodal correspondences that has involved typeface (e.g., Velasco et al., 2014, Velasco, Woods, Hyndman, & Spence, 2015; Velasco, Woods, et al., 2018; Venkatesan et al., 2022; cf. Sousa et al., 2020), the typeface stimuli used to conduct the experiments were selected from fonts created by established foundries (i.e., fonts with a prevalent presence and possibly familiar to the assessors). Among the five studies reviewed by Velasco and Spence (2019) that had assessed the role of typeface on shaping taste expectations and perception, all appear to have examined the typeface–taste association with existing fonts. At the same time, some researchers have drawn fonts by hand to study the crossmodal effects of typeface (e.g., Rolschau et al., 2020). While these approaches have been shown to have effectively demonstrated the effects of typeface curvilinearity, they have not adequately controlled for other typeface properties. These include, but are not limited to, stroke width, x-height, filling method, and counter ratio. Importantly, these properties make up the typeface composition that determines the legibility of, and possibly the preference for, a given typeface (Li & Suen, 2010; L. Wang et al., 2020). Relevant here, previous theories on the origins of vision–taste correspondences have tentatively suggested the role of preference (or emotion) as a mediating factor when establishing associations between crossmodal features such as geometric shapes and taste qualities (see Spence, 2020, 2022b; Whiteford et al., 2018). When taking the effect of preference into consideration, typefaces that are favored by the reader/observer might have a higher chance of being associated with sweet taste (Schifferstein & Tanudjaja,

[1] The hex code for colour pink was #FFC0CB in Woods and Spence's (2016) study, which deviates slightly from the web-safe hex code of pink. The revised web-safe colour code for pink (#FCC/#FFCCCC) was used in the current study. Note, however, that the two colors are almost visually identical.

Figure 4

The Color Combinations Most Strongly Associated With Each of the Four Basic Tastes in Woods et al.'s (2016) Study



Note. The higher a color scheme is in a column, the more strongly it was associated with the respective taste. Depending on the viewer's perspective, this could either be seen as a color sitting on top of another color (foreground–background configuration) or a color surrounded by another color (body–outline configuration). See the online article for the color version of this figure.

2004; Sukkwai et al., 2017). If the emotions evoked by the typeface stimuli were modified by some typeface properties other than the curvilinearity, such as past experiences with the font (Bernard et al., 2002), the associations documented between taste and curvilinearity could be confounded by those properties.

To ensure the differences between typeface conditions were limited to their stroke curvilinearity, two typefaces were developed specifically for use in the present study. We took three aspects into consideration when designing them: First, the typefaces should have comparable stroke widths in boldness/weight to create similar surface area for the letters, thereby ensuring a consistent level of legibility between the two conditions (Beier & Oderkerk, 2019). Second, they should not deviate drastically from the fonts that have been used in previous crossmodal correspondences research, as those fonts were already proven to be reliably associated with the hypothesized taste (e.g., Velasco, Hyndman, & Spence, 2018). Third, the different conditions should provide the same level of readability when applied to a text to maintain a similar processing speed between conditions (Brumberger, 2004; Hill, 1997). Maintaining readability means that the letters should not be overly stylized (i.e., advocating for briefness over ornament), and the kerning distance for each typeface should require minimum adjustment. To meet these needs, two open-source typefaces under SIL Open Font Licence (Spalinger & Gaultney, 2007) were substantially modified to create a rounded (modified from "Gensen Source"; Zihi & Adobe, 2020) and an angular typeface (modified from "Tomorrow"; de Marco & Rizzolli, 2019) for the present study (see Figure 5; Appendix). The current study used the phrase "Taste like" as the text sample for visual stimuli, the phrase has been demonstrated in previous research to effectively influence taste expectations when manipulating typeface curvilinearity (Velasco, Hyndman, & Spence, 2018).

Design

The study adopted a 2 (curvilinearities: rounded, angular) × 20 (coloring schemes: five top-matching combinations for each of the four basic tastes) within-participants experimental design. Each participant viewed and evaluated the 40 text stimuli presented in random order (see Figure 6). Participants viewed only one stimulus at a time, with four scales (each for a basic taste) available to the participants at the same time. They were asked to rate the strength of association between the presented stimulus and each of the four basic tastes (sweet, sour, salty, bitter) on individual 10-point Likert scales for each taste (see Velasco, Hyndman, & Spence, 2018, Experiment 2).

Procedure

Participants received instructions concerning the experiment upon loading the welcome screen. Before the actual trials started, the participants completed a practice question. The participants then went through the 40 text stimuli in random order, resulting in 40 trials for each participant (see Figure 7). For each text stimulus, the participants were prompted with "How strongly would you associate this colorful typeface/font with each of the four basic tastes?" alongside the stimulus. While viewing the stimulus, the participants estimated the strength of association with four basic tastes on a scale from 1 (*least strong*) to 10 (*strongest*). The display order of the four scales was randomized across participants. Participants stayed on the same page when deciding on all four taste ratings, the time spent on a page from first seeing the stimulus to submitting all taste ratings (which were submitted at once) was recorded as RTs to decide on the taste ratings for that text stimulus.

Analyses

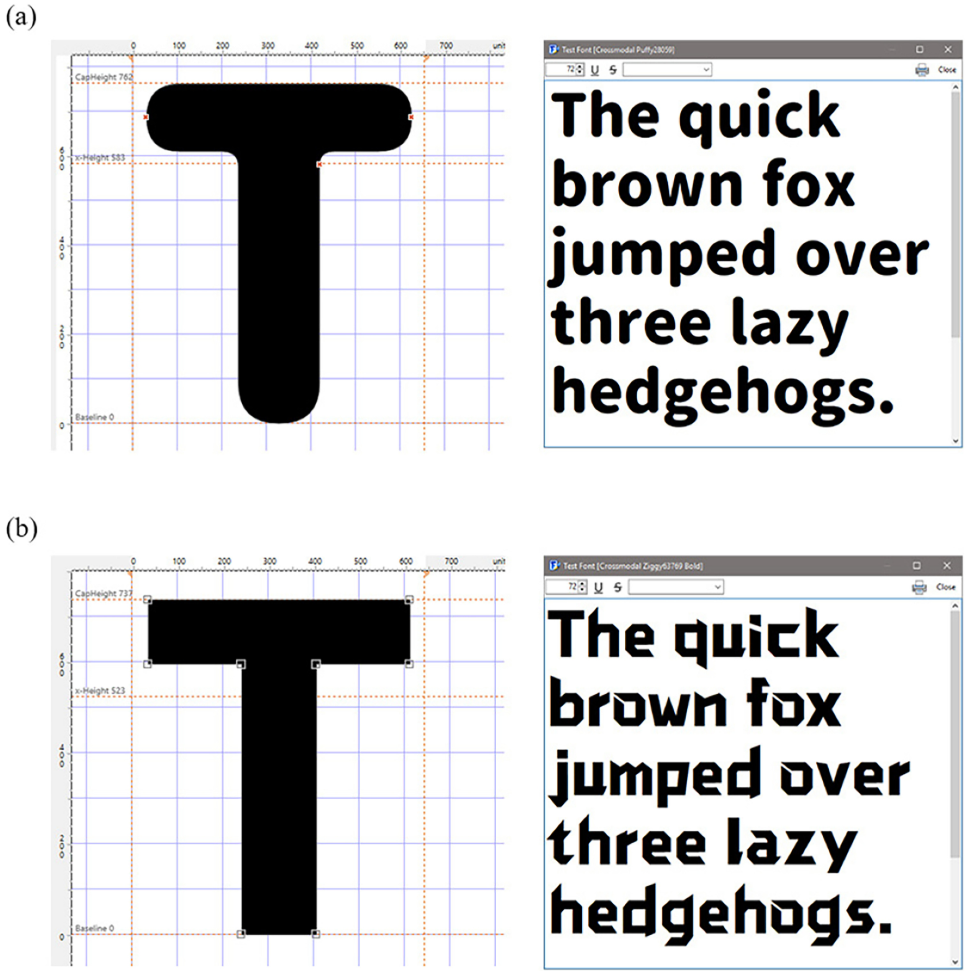
Nonparametric tests (Wald-type statistic) for the interaction in a Within × Within the type of two-way factorial design (Feys, 2016) were used to assess and determine the effect of the interaction between typeface curvilinearity and coloring schemes in the estimated taste strengths for each basic taste quality. The factorial structure followed the 2 (curvilinearity: rounded, angular) × 20 (coloring schemes) within-participant design, with the dependent variable being the estimated taste strengths for each of the four basic tastes (sweet, sour, salty, and bitter). The analyses were performed in the RStudio software with the nparLD package developed by Noguchi et al. (2012), and the nonparametric tests were performed with the ld.f2 function (Brunner et al., 2002, see Feys, 2016) in the package.

Results

The analyses revealed a statistically significant interaction between color scheme and typeface curvilinearity for the estimated strength of sweet, $F(1, 19) = 40.71$, $p < .005$, sour, $F(1, 19) = 68.80$, $p < .0001$, and bitter, $F(1, 19) = 44.38$, $p < .001$, though with the effect for salty only achieving borderline significance, $F(1, 19) = 29.80$, $p = .054$. Simple main effects analysis revealed that both coloring scheme and typeface curvilinearity had a statistically significant effect on the association strength of each basic taste ($p < .001$). Power analysis conducted with GPower (Erdfelder et al., 1996) indicates that for the present design (2 × 20 within-participant factorial design) based on a medium effect size ($f = .25$), α level of

Figure 5

The Rounded (a) and Angular (b) Typefaces Designed for the Current Study



Note. See the online article for the color version of this figure.

.05, sample size of 102, and correlation among repeated measures of .50, the actual power was calculated to be 0.82.

Figure 8 shows how taste ratings (estimated strength of association) vary with the appearance of text stimuli for each basic taste. Coloring schemes are represented by columns and illustrated accordingly. Within the same column, typeface curvilinearity is represented by the shape of data points: square for the angular typeface and circle for rounded. Notably, there is an overlap between the two typeface conditions in the taste ratings of sourness when the text was presented in one of the "sour-tasting" color schemes (see Figure 8b). A post hoc analysis was performed to understand the effect on taste ratings of five coloring schemes that were previously found to associate with sour taste (green text body with yellow, red, purple, black, and no outline). The Wald-type test revealed no significant interaction between the effects of typeface curvilinearity and coloring schemes on sour taste ratings, $F(1, 4) = 1.25$, $p = .87$. When only looking at the "sour-tasting" coloring schemes, simple main effects analyses revealed a significant effect of color on sour taste ratings, $F(1, 4) = 22.58$, $p < .001$, but not of typeface curvilinearity, $F(1, 1) = 2.61$, $p = .11$.

To further explore the differences between the color conditions, post hoc pairwise comparisons were conducted, for each basic taste, between coloring schemes that are found to be most strongly associated with the same taste quality. With Bonferroni correction applied, the Wilcoxon signed-rank test revealed significant differences between some of the most-associated coloring schemes for all four basic tastes (see Figure 9). When comparing the strength of association between the top five most strongly associated color schemes for each basic taste, the analysis for "salty-tasting" colors revealed only one significant difference (see Figure 9c), whereas at least three significant differences were observed for sweet, sour, and bitter tastes. The only significant difference was found between the white text body with a blue outline and that with a red outline ($p < .001$). Unlike other tastes, no difference was found between the "salty-tasting" coloring scheme without an outline (i.e., white text body only) and any of the outlined counterparts.

For the RTs, the interaction between the effects of coloring schemes and typeface curvilinearity did not reach significance, $F(1, 19) = 28.70$, $p = .071$. A significant main effect of coloring schemes was observed ($p < .005$), but there were no differences between RTs of stimuli rendered in different typeface curvilinearity

Figure 6

All 40 Styles of Text Stimuli Evaluated by Each Participant in the Current Study Arranged in Columns of Corresponding Taste Quality According to the Results of Woods et al. (2016)

Note. Two typefaces of different curvilinearity (top: rounded, bottom: angular) are applied to each coloring scheme. The higher a color scheme appears in the list, the more strongly it had been associated with the respective taste in Woods et al.'s (2016) previous study. See the online article for the color version of this figure.

($p = .86$). After collapsing typeface curvilinearity and separating coloring schemes into four groups by the most strongly associated taste quality according to the previously documented mappings (Woods et al., 2016), a Friedman test revealed that the RT was only significantly different between the coloring schemes most strongly associated with sweetness, $\chi^2(4) = 10.1$, $p < .05$, $W = 0.01$, a small effect size was detected using Cohen's interpretation guidelines, $W = 0.01$. A follow-up pairwise Wilcoxon signed-rank test between the "sweet-tasting" coloring schemes revealed statistically significant differences in RT between plain pink text and pink text with purple outline ($p < .05$), as well as plain pink text and pink text with red outline ($p < .05$). The participants were faster at assigning the taste associations of plain pink text ($M = 10.2$ s, $SD = 4.6$) than both pink text with purple outline ($M = 11.3$ s, $SD = 5.7$) and pink text with a red outline ($M = 11.3$ s, $SD = 5.2$).

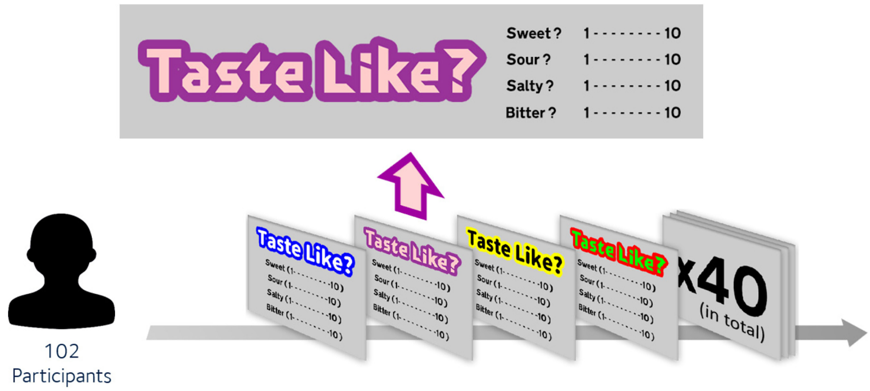
Discussion

The study reported here examined the respective roles of color scheme and typeface curvilinearity in the vision–taste correspondences between different styles of text presentation and basic taste qualities (i.e., sweet, sour, salty, and bitter), with a specific interest in the possible combined effects of color and typeface in these correspondences. In summary, the results demonstrate the influence of color and curvilinearity, as text properties, on the strength of association with each basic taste quality. In terms of the effect of coloring schemes, the results are in line with the findings of previous studies of color–taste correspondences (Woods et al., 2016; Woods & Spence, 2016). Reassuringly, the coloring schemes more strongly associated with each taste were also the same foreground–background color pairs previously found to be most strongly associated with each taste quality. For each taste quality displayed in Figure 8, there are noticeable "plateaux" of estimated association strength, which could indicate a cluster of coloring schemes that are more connected to the respective taste than the others.

Given that the coloring schemes presented in the study were selected from the color combinations that had previously been found most strongly associated with each taste (Woods et al., 2016), it is unsurprising (if not anticipated) that the text stimuli can be grouped into four clusters by the strength of association for each taste quality. Figure 10 provides a more intuitive perspective on the clusters of coloring schemes. It appears that the sweet and sour taste (Figure 10a, b) each has a cluster of coloring schemes standing out from the others (e.g., all the pink-colored text gave similar strength of association with sweet). In comparison, the grouping of coloring schemes for salty and bitter taste are slightly more ambiguous. It is intriguing to note that the participants found "bitter-tasting" colors to have a strong association with saltiness (see Figure 10c) while the "sour-tasting" colors were regarded almost as bitter as the "bitter-tasting" ones (see Figure 10d). Admittedly, the confusion surrounding basic taste qualities has been well documented in the literature (e.g., the sour-bitter confusion; Doty et al., 2017; O'Mahony et al., 1979). Nevertheless, it is curious to see the confusion occurs in a seemingly unidirectional manner here (i.e., "sour-tasting" stimuli are found to be associated with bitterness, but not vice versa).

As has been documented previously (Velasco, Woods, Hyndman, & Spence, 2015; Velasco & Spence, 2019), the rounded typeface is found to prime expectations of a sweeter taste, while the angular

Figure 7
Mock-Up of the Procedure That All Participants Went Through in the Present Study



Note. See the online article for the color version of this figure.

typeface appears to prime other tastes instead (sour, salty, and bitter). Importantly, the simple effect of typeface curvilinearity suggests that typeface curvilinearity alone can exert an influence over the estimated strength of associations between taste and visual features (cf. Stewart & Goss, 2013). However, there is no typeface effect in sour ratings when the stimuli were applied with the so-called "sour-tasting" coloring schemes (green body with various outline colors; see Figure 11). In fact, even the stimulus that has a black text body with a "sour-tasting" yellow outline does not appear to have a typeface effect on the strength of association with sour, a post hoc Wilcox comparison between the rounded and angular text in this coloring scheme revealed no significant difference between the two typeface conditions ($p = .72$).

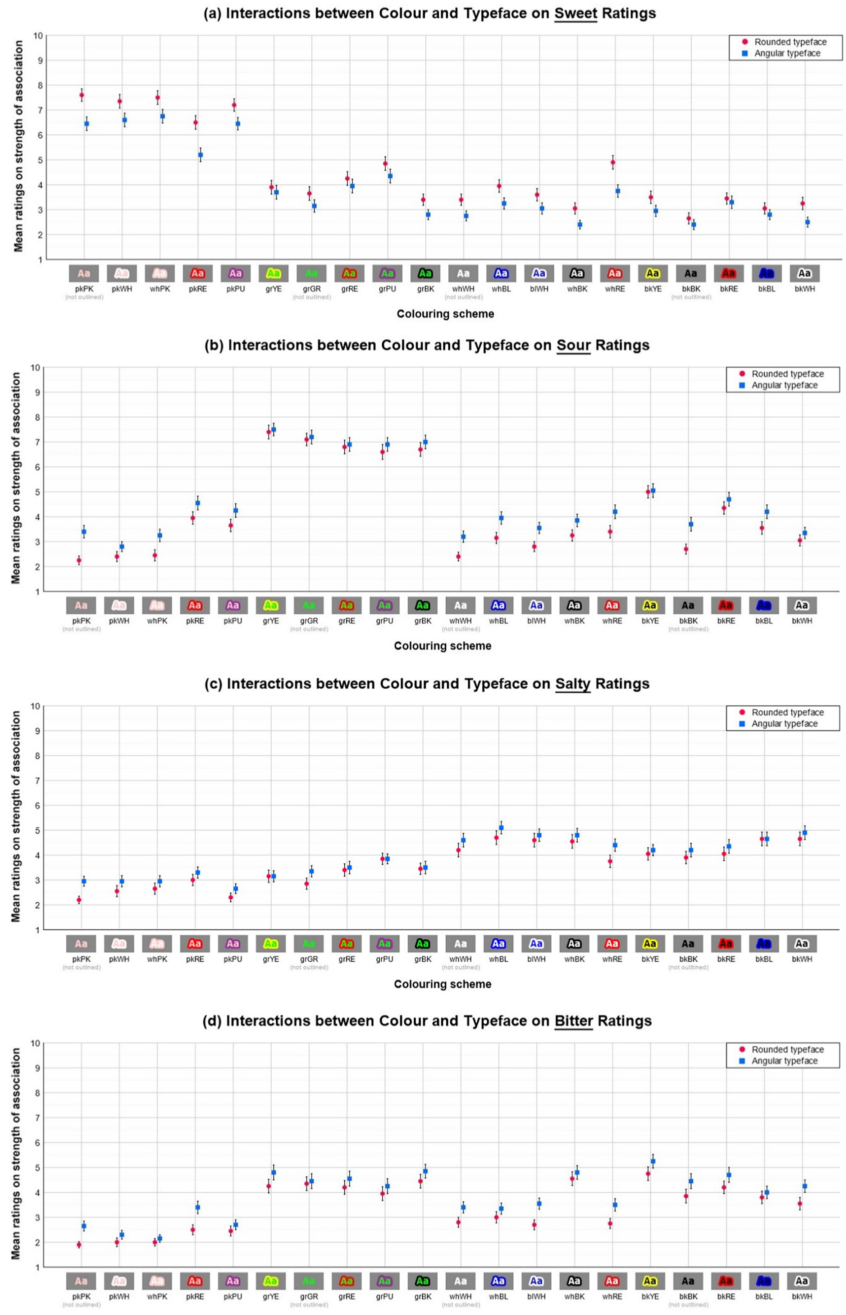
While there would appear to be a lack of typeface effects on the expectation of sour when the text happens to feature "sour-tasting" colors, our results nevertheless show the congruent pairing of color and typeface could further modify the strength of taste expectations. For example, rounded pink text was found to be more strongly associated with sweetness than angular pink text, while rounded white text seems to have discounted (lowered) the sour ratings when compared to the angular white text. Coloring scheme is clearly a more influential property of text than typeface curvilinearity. It is evident that the strength of association can vary drastically on the scale (see Figure 8) across dissimilar coloring schemes (comparing data points between columns), whereas the differences introduced by typeface curvilinearity (comparing the circle and square points in the same column) are much more modest in contrast—albeit generally still significant. To put this into perspective, color would appear to determine which taste quality (or qualities) a text is associated with, while typeface only nudges the strength of that association in the corresponding direction. People have been known to use the verbal terms of geometric features to describe taste profiles (e.g., "that cheese tastes sharp"; Chamberlain, 1903; Marks, 1978; Spence, 2022b), which has led to early suggestions of taste-shape correspondences (Cytowic, 1989; Cytowic & Wood, 1982; Dichter, 1971; Gal et al., 2007). It is thus a peculiar finding that color could potentially exert a dominant influence over the shape in terms of setting vision–taste associations, given that people rarely describe tastes in terms of colors (e.g., "something tastes green").

In Rolschau et al.'s (2020) field study, customers made counterintuitive purchasing decisions when presented with a chalkboard menu featuring the names of beers. Their findings could be potentially explained by the putative inhibition of typeface effect (i.e., curvilinearity–taste association) when the text is presented in specific coloring schemes. Since the beer items on their menu had applied the same color across different typeface settings, those items written in green or yellow may also have suffered a lessened or even inhibited typeface effect. The key question to be addressed here is what made people stop relying on typeface properties when deciding on the corresponding taste profile. In response, we tentatively propose the idea of believable modification for this probable interference between color and typeface. Essentially, to prime different taste expectations in observers, the modification has to be within a reasonable range and to conform to the general knowledge people hold about food experience (F. M. Carvalho & Spence, 2019). Should this explanation be applied to the present study, it could be seen that the "sour-tasting" coloring schemes such as green or yellow have increased the strength of the association between text stimuli and sour taste to the point where there is very little room for typeface to impose its influence.

Our study, with a paradigm that allows the examination of interactions between color and typeface, contributes valuable insights to the ongoing exploration of the origins of crossmodal correspondences. The two types of visual stimuli involved here, color hues and typeface curvilinearity, are proposed to have different underlying mechanisms for their association with taste qualities. According to popular theories, color hues are associated with taste qualities based on the statistics of the environment that have been internalized in the mind of the observer (Barlow, 2001; Spence & Levitan, 2021), while curvilinearity properties may depend on the mediation of emotions (Spence, 2022b, 2023; Velasco, Woods, Deroy, & Spence, 2015). Although these theories on the acquisition of crossmodal correspondences have been reasonably supported by the empirical evidence that has been published to date (Salgado-Montejo et al., 2015; Shankar et al., 2010; Velasco, Woods, Deroy, & Spence, 2015), their combined operation, such as in a paradigm presented here, has rarely been explored. The interaction effects observed in the current study suggest that the two origins can indeed operate synergistically, as the congruent pairing of

Figure 8

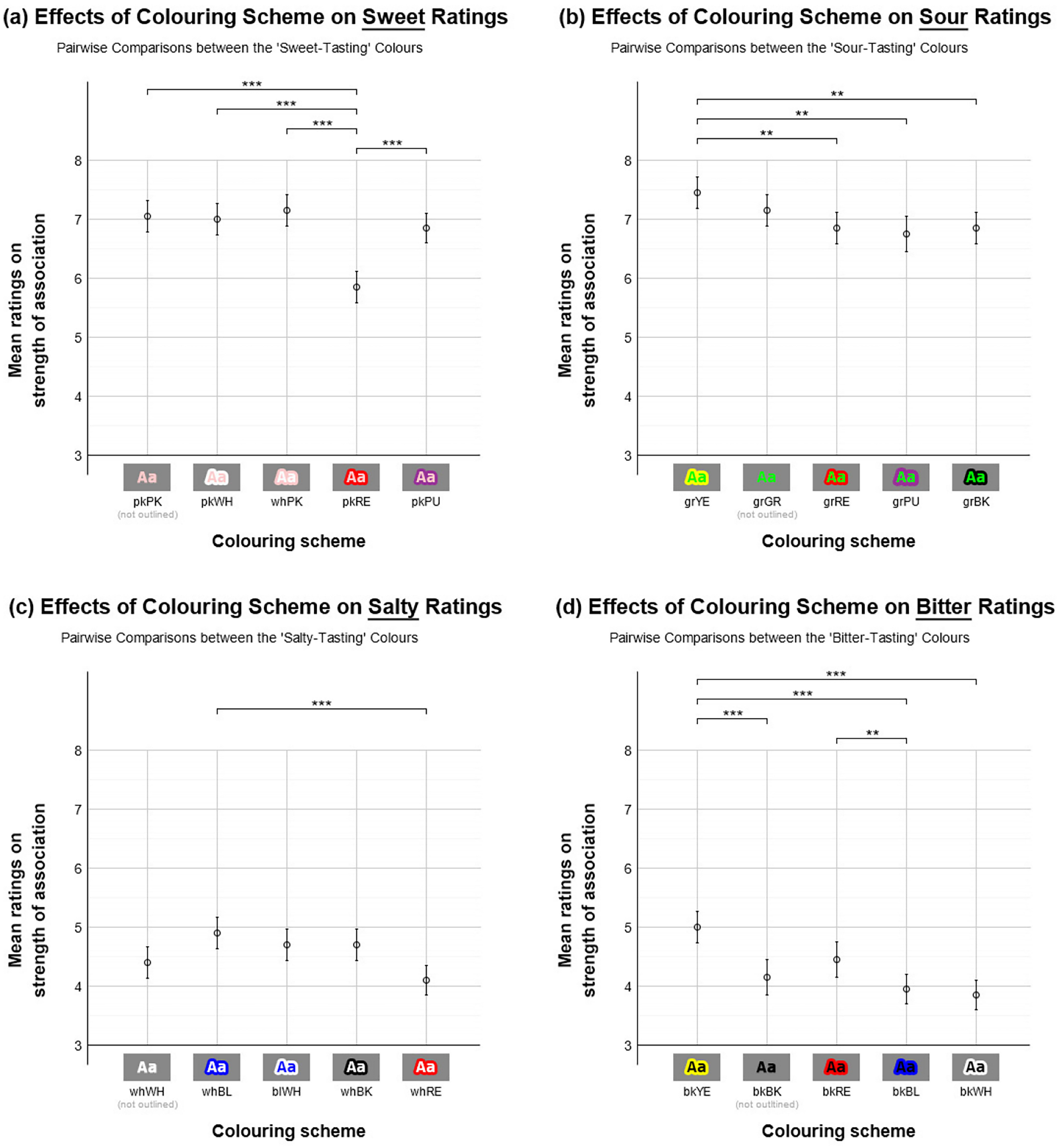
Effects of Text Stimuli on the Strength of Association With the (a) Sweet, (b) Sour, (c) Salty, and (d) Bitter Taste



Note. Scatter plot points represent the average strength of taste association estimated by the participants. A higher point indicates a stronger association between the stimulus and the respective taste. Each column (vertical division) indicates a coloring scheme, labeled as lowercase letters for the body color and uppercase letters for the outline color. Color hues are coded as PK, WH, RE, PU, GR, YE, BK, and BL for pink, white, red, purple, green, yellow, black, and blue. The coloring schemes in the figure are grouped by the taste they were previously found to associate with most strongly, in the order of (from left to right) sweet, sour, salty, and bitter. Error bars represent standard errors. See the online article for the color version of this figure.

Figure 9

Main Effect of Color Analyzed With the Top-Matching Coloring Schemes in (a) Sweet, (b) Sour, (c) Salty, and (d) Bitter Taste

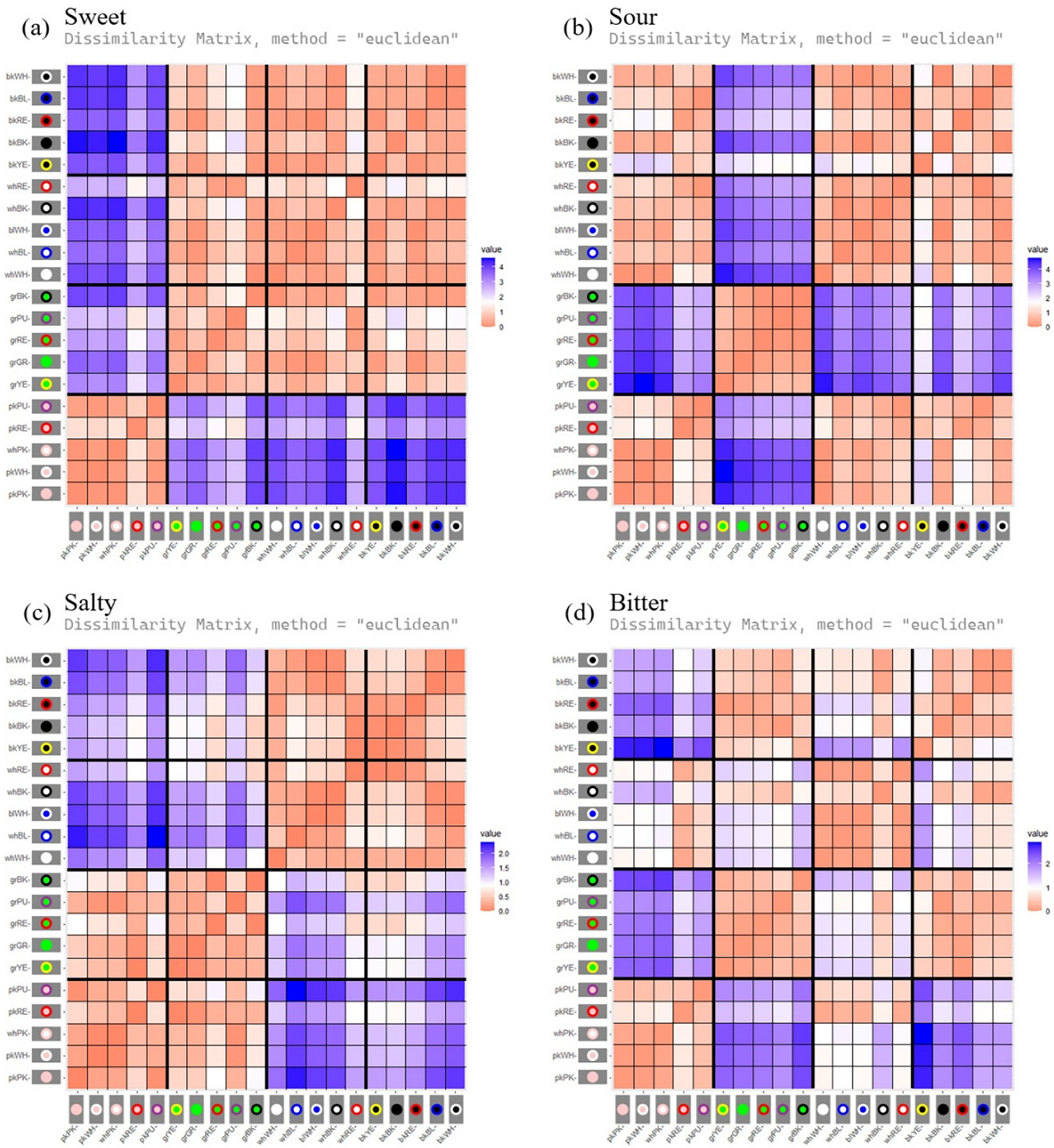


Note. The y-axis in this particular figure ranges from 3 to 8 for a better focus on the data. The four panels present the differences in the average strength of taste association of the four basic tastes between the five top-matching coloring schemes (i.e., schemes that are found to be most associated with the respective taste). Error bars represent standard errors. See the online article for the color version of this figure.

color and typeface can create a stronger association with the corresponding taste. It is evident that the emotional valence associated with color hues (Palmer & Schloss, 2010) did not prevent the typeface effects from priming taste expectations, which, as an extension of geometric curvilinearity, would also rely on the mediation of emotions in forming vision–taste associations.

Figure 10

Cluster Analysis of Different Coloring Schemes With Dissimilarity Matrix Plots for (a) Sweet, (b) Sour, (c) Salty, and (d) Bitter Taste

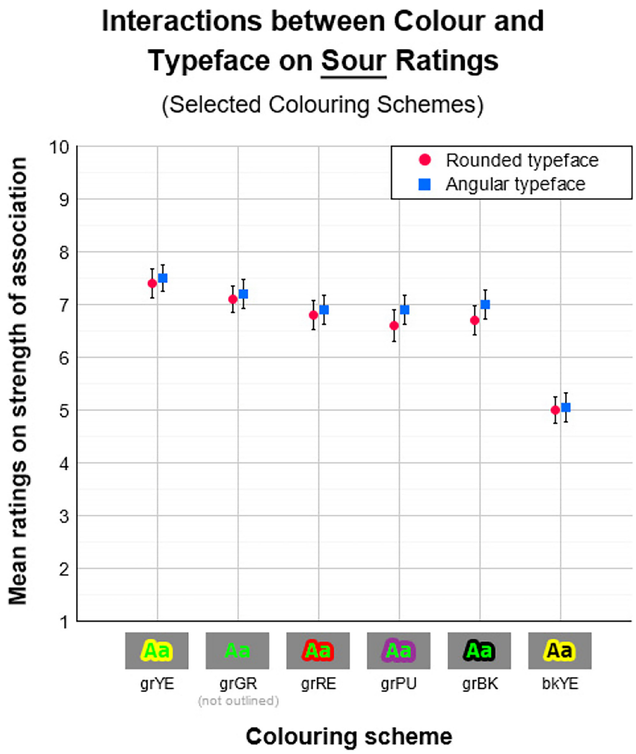


Note. Typeface curvilinearity has been collapsed for the cluster analyses. The coloring schemes are illustrated with a small circle (representing the text body) sitting on top of a larger circle (representing the text outline). The more similar a pair of color schemes is in terms of its association strength, the more saturated and warmer (or "more orange") their respective intersection square is. See the online article for the color version of this figure.

Taking the analysis one step further, the interaction effects observed here could also suggest a system of hierarchy, or priority, when people make crossmodal associations, with a possible preference for internalized statistics over emotional mediation when establishing color–taste associations (cf. Whiteford et al., 2018). Evidence for this notion is found in the color–taste

Figure 11

Comparing the Relative Effects of the "Sour-Tasting" Text Stimuli on the Strength of Association With Sour Taste



Note. Scatter plot points represent the average strength of taste association estimated by the participants. A higher point indicates a stronger association between the stimulus and sourness. Each column (vertical division) represents a coloring scheme, labeled as lowercase letters for the body color and uppercase letters for the outline color. Color hues are coded as RE, PU, GR, YE, and BK for red, purple, green, yellow, and black. Color schemes selected for display here feature at least one color that has been documented by previous studies (e.g., Wan et al., 2014; Woods et al., 2016) to associate strongly with sour taste. Error bars represent standard errors. See the online article for the color version of this figure.

associations reported by our participants, which are generally in line with the proposed regularities in the environment and previously documented patterns (Spence et al., 2015). It should also be noted that since the participants were supposedly forced to assess the visual features collectively (if not holistically, see Wagemans et al., 2012), they could have an equal opportunity to access the hedonic values associated with colors as they do with typeface curvilinearity (Bertamini et al., 2013). Additionally, the stronger influence of color associations, when compared to typeface curvilinearity associations, may point to an underlying relationship between the power of a type of visual stimuli and its origin of crossmodal correspondences. Further investigation is required to clarify the exact nature of this connection and the broader implications for understanding crossmodal correspondences (B. P. Lee & Spence, 2023).

In addition to the estimated strength of association of each taste quality, the study also measured the RT of each text stimulus. The interest in examining the effects on RT was inspired by the previous discussion on unitary Gestalt experience when making crossmodal associations (Köhler, 1929; Woods & Spence, 2016; Woods et al., 2016), which could be partially reflected by the time it took to process the stimulus. The analyses tested whether applying an outline color to the text would create significant differences in terms of the RT when inferring the taste profile. The results suggest no significant differences in RTs between plain text stimuli and their outlined counterparts, with the exception of plain pink text and pink text with a red/purple outline. In general, the participants did not require more time to assess the taste profile of plain mono-colored text than those with an outline in another color. It is worth pointing out that the differences in RTs in the present study do not appear to fluctuate as much as they did in Woods et al.'s (2016) study of abstract colors. It is also reassuring to see that the coloring schemes with limited contrast between the constituting colors (e.g., pink text with white outline; see Table 2) did not take observers longer to decide the taste ratings than the more contrasting schemes. This observation effectively alleviates concerns that the questionable visibility of certain color pairs may prolong the time required for participants to process the stimuli and decide on the taste correspondences.

While the visual stimuli in this study were presented in isolation (i.e., the participants were not given any context about the stimuli), it is anticipated that the patterns of vision–taste crossmodal correspondences reported here can be translated to graphic elements in other contexts (Sugimori & Kawasaki, 2022; Van Doorn et al., 2017; Velasco, Michel, et al., 2016; Wan et al., 2014, 2016). There is a promising prospect that the effects observed in this study could extend to the interaction between color hues and simpler geometric shapes, especially given that the taste correspondences of shapes, similar to those of typefaces, are predominantly driven by the emotional mediation of curvilinearity properties (Spence, 2023; Velasco, Woods, Hyndman, & Spence, 2015; Q. J. Wang & Spence, 2018). Moreover, previous research has also demonstrated the synergetic interactions between color and shape of food container in collectively influencing taste perception (Stewart & Goss, 2013) and product preference (Chitturi et al., 2019). Thus, we would expect to see these findings applied to a range of scenarios involving food and text display, as it has already been demonstrated that the curvilinearity–taste effects of typeface could influence taste expectations when displayed in various contexts (Sousa et al., 2020; Velasco & Spence, 2019; Velasco, Hyndman, & Spence, 2018; Velasco et al., 2014). In light of these findings, designers interested in harnessing the synergy of visual features could reasonably expect there to be a similar interaction effect between color and typeface curvilinearity in their works. Although arguably less practical, it would not be so surprising to see our findings extended the implication to product-intrinsic elements (i.e., the appearance of food instead of packaging; e.g., Blackmore et al., 2021; Johnson & Clydesdale, 1982; Piqueras-Fiszman et al., 2012; Spence et al., 2015; Ueda et al., 2020) such as, as an example, chocolate beans with letter decoration (see Figure 12).

While the current study has successfully demonstrated the effects of interest, several limitations in the experimental design warrant further attention. One important consideration, as highlighted by the recent explorations (F. M. Carvalho & Spence, 2019; Chuquichambi et al., 2021), remains the influence of familiarity in mediating affective correspondences between taste quality and typeface curvilinearity (Otterbring et al., 2022). Theoretically, the customized typeface stimuli should have mitigated the effect of prior exposure, but a more elegant and rewarding approach (in terms of isolating the familiarity effect) would involve contrasting a common typeface and its variants with exaggerated curvilinearity features.

Table 2
Color Distances Between the Colors Applied to the Stimuli as Pairs in the Present Study

Color	Pink	White	Red	Purple	Green	Yellow	Black	Blue
Pink	0	—						
White	23.58	0	—					
Red	92.74	114.60	0	—				
Purple	72.37	88.35	105.94	0	—			
Green	N/A	120.42	170.68	190.08	0	—		
Yellow	N/A	N/A	N/A	N/A	66.28	0	—	
Black	N/A	100.00	117.34	N/A	148.47	137.21	0	—
Blue	N/A	149.96	N/A	N/A	N/A	N/A	137.66	0

Note. These distances represent the Euclidean linear distance (International Telecommunication Union, 2019) of two colors, meaning that the underlying color space is not perceptually uniform. The longer the distance is between two colors, the more contrasting the pair will be when presented together. "N/A" stands for color combinations that were not investigated as stimuli. As the name suggests, the problem with this approach is that the values do not necessarily reflect how perceptually different the two colors are to the observers. Nevertheless, the lack of contrast between pink and white is quite evident as shown in the table.

Such a "common typeface" could be one that is ubiquitous in daily life, like those displayed by default in mainstream user interfaces. Another limitation of the study, or rather a confounding factor that could easily be overlooked, concerns the potential conflict between the hedonic value of color and that of curvilinearity. The conflict, if confirmed, may explain the lack of typeface effect when text stimuli were in green or yellow coloring schemes, which have been situationally found to be the colors on the negative end of the spectrum (Schaie, 1961; though the preference for colors is undoubtedly subject to context; e.g., see Schloss et al., 2012). Relevant here, we find ourselves in a position that would greatly benefit from the use of semantic differential technique (see Osgood et al., 1957/1967) in building a more comprehensive model of mediating emotions when matching crossmodal associations (e.g., Motoki et al., 2022), which could offer a tool for future studies to not only capture the effect of other feelings (e.g., familiarity and arousal; Q. J. Wang et al., 2016), but also compare the power of valence associated with different sensory features, such as hue and curvilinearity.

The findings reported here demonstrate the existence of interaction between visual features in the crossmodal associations involving taste quality, color hue, and typeface curvilinearity. For those interested in the wider application of crossmodal correspondences, such as researcher and market practitioners alike, it is reassuring to see evidence of people integrating visual features when deciding on the associated taste qualities. Importantly, there appear to be varying degrees of dominance of color effects over the influence of typeface curvilinearity. The coloring scheme of the stimulus appears to determine the taste quality that the stimulus is most associated with, while the typeface curvilinearity could only modify the strength of association to a lesser degree. In some extreme cases, such as when the stimulus is in a typically "sour-tasting" coloring scheme, there might even be a lack of typeface effect on taste expectations. Crucially, our findings of synergetic interactions between color and curvilinearity suggest a degree of compatibility between theories explaining the origin of vision–taste crossmodal correspondences, as these two visual features are generally believed to originate from different principles of establishing matching between the visual features and taste qualities. To gain a better understanding of what could have led to this effect when presenting multiple visual features, further research will need to study the interaction between typeface curvilinearity and color schemes at varying levels (e.g., different color saliency and degree of curvature). Along such lines,

Figure 12
Mock-up of Chocolate Beans Coated of Assorted Colors With a Letter in Typefaces of Different Curvilinearity on the Top

Note. See the online article for the color version of this figure.

further research could also address the role of additional visual properties of typeface, such as counter spacing, font weight, and other previously omitted features with documented influence on viewer preference (L. Wang et al., 2020).

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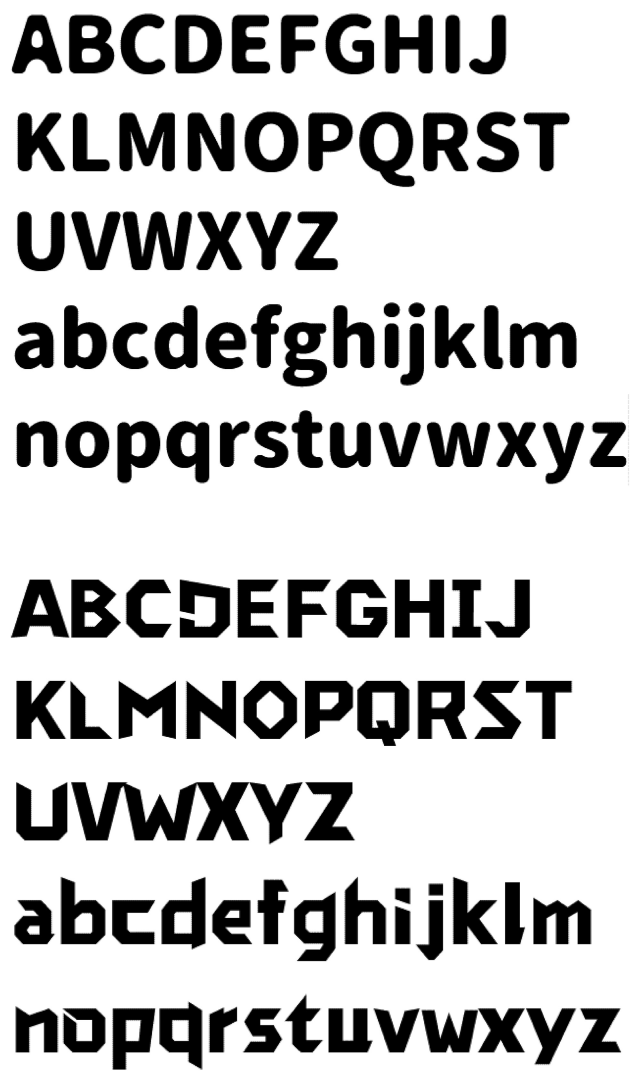
(*Appendix follows*)

Appendix

Type Specimen of "Puffy" (Top) and "Ziggy" (Bottom)



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