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The sweetest punch: Effects of 3D-printed surface textures and graphic design on ice-cream evaluation

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ABSTRACT

Research shows that design factors of packaging and food containers can have a strong impact on taste experience and product evaluation. However, so far research has mainly focused on how visual appearances steer sensory impressions including smell and taste. Taking into account new (technological) developments in packaging design, this research investigates the impact of 3D-printed surfaces on taste evaluation of two ice cream variants. In addition, the interplay between surface textures and matching or non-matching shapes presented on a poster in the consumption environment (i.e., an ice-cream salon) was studied. To this end, 3D-printed cups with either a sharp or smooth surface were manufactured and used in a taste session conducted at an ice-cream salon, where either a poster with sharp or smooth shapes was hanging down the wall. Results testify to the potential of influencing taste evaluations by means of surface textures, with a smooth surface enhancing sweetness evaluation, and a sharp surface enhancing intensity evaluations. Furthermore, findings might imply that mismatches between surface textures and poster design may enhance product and taste liking.

1. Multi-sensory design and food experience

When consuming foods and drinks, we do so from cans, bottles or boxes which apart from visual factors also incorporate tactile elements. Think for instance of matte surface textures which may be used by beer brands or soft drink manufacturers to grant their products a more masculine or rough image. Alternatively, skin care brands may present their products in soft-touch packaging designs to highlight their soothing or skin-nourishing effects. Made possible by developments in 3D printing and advanced coating technologies, in the years to come, packaging designs will increasingly appeal to our sense of touch by means of such surface textures.

Underscoring the potential and relevance of packaging design to people's food and drink experiences, a considerable body of research shows that evaluations not only vary with food characteristics or ingredients, but also with (packaging) factors such as color, shape, and textures (e.g., Becker, Rompay, Schifferstein, & Galetzka, 2011; McDaniel & Baker, 1977; Piqueras-Fiszman & Spence, 2011; Rao & Monroe, 1989). For instance, Becker et al. (2011) showed that yogurt taste associated with an angular, rather than a rounded, package was evaluated as stronger and more intense. A follow-up study showed that when such angular elements are embedded in surface textures, similar effects can be observed; bitterness ratings were enhanced for participants who tasted coffee from a sample cup with an angular (as opposed to a rounded) texture (Van Rompay, Finger, Saakes, & Fenko, 2017). Such findings testify to the potential of shaping food experiences through look and feel properties of packaging design. Although researchers have studied food and beverage evaluation as a function of tactile properties (e.g., Krishna, 2012; Piqueras-Fiszman & Spence, 2012, 2015; Schifferstein & Cleiren, 2005; Spence, 2016; Spence & Wan, 2015), studies systematically assessing the influence of 3D printed surfaces on food and drink experience are few.

In addition to packaging design, promotional elements such as posters or banners present in the consumption area may also accentuate specific taste sensations. For instance, Van Rompay et al. (2017) showed that a slogan presented on a poster highlighting a drink's *strong* (as opposed to *soft*) taste enhanced corresponding taste intensity ratings, a finding in line with previous research showing that tastes are liked better when they are matched with related (rather than unrelated) words (Distel & Hudson, 2001; Herz & von Clef, 2001; Okamoto et al., 2009). In other words, when evaluating taste, customers may integrate impressions generated by different sources. In addition to studying the effects of surface textures on taste and product liking, a second aim of this research lies in studying this interplay between sensations generated by surface textures and visual shapes (portrayed on promotional posters) respectively.

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The study presented in this paper took place in a Dutch ice cream salon where participants tasted a sweet vanilla ice cream or a sour lemon ice cream from either a sample cup with a sharp surface texture or from a sample cup with a smooth surface. A large promotional poster (either presenting sharp shape features or smooth shape features) was hanging down from one of the walls. In addition to studying effects of surface textures on basic taste sensations (sour and sweet in this research), we were thus also interested in seeing if and how poster design would possibly modify effects of surface textures on product and taste liking. Before elaborating on the details of this study, first we will present an overview of the key notions involved.

2. Effects of materials and textures on food perception

In recent years, research has persuasively shown that our evaluations of foods and drinks are shaped by a wide variety of design factors. For example, people's perceptions of wine odor and aroma differ as a function of the shape of the glass in which the wine is served (e.g., Hummel, Delwiche, Schmidt, & Hüttenbrink, 2003; Vilanova, Vidal, & Cortés, 2008), and cheesecake is experienced as sweeter when consumed from round (as opposed to square) plates (Stewart & Goss, 2013). In addition to such effects of shape, different materials also make for different taste experiences (Biggs, Juravle, & Spence, 2016; Piqueras-Fiszman & Spence, 2012; Spence & Wan, 2015; Tu, Yang, & Ma, 2015). For instance, Biggs et al. (2016) showed that biscuits tasted saltier when sampled from a rough, rather than a smooth, plate. Finally, Van Rompay et al. (2017) showed that a hot chocolate drink tasted even sweeter when sampled from a cup with a rounded surface texture. Although these studies clearly underline the effects of shape and material properties on drink and food perception, experimental research specifically addressing transfer effects from 3D printed surfaces to taste perception is limited (cf. Spence & Wan [2015]; Spence [2016]).

In terms of the (psychological) mechanisms involved, these findings clearly show that people intuitively make connections between different sensory domains, a phenomenon referred to as 'cross-modal correspondence' (e.g., Crisinel, Jacquier, Deroy, & Spence, 2013; Spence & Gallace, 2011; Velasco, Woods, Petit, Cheok, & Spence, 2016). For instance, across food and beverage categories (including cheese, tea, yoghurt, fruit juice, and chocolate), cross-modal correspondences have been revealed between shape and basic taste evaluations (e.g., bitterness and sourness). Ngo, Misra, and Spence (2011), for instance, visually presented different shapes in combination with different types of chocolate, and showed that sweetness is readily associated with smooth, organic shapes.

The theoretical basis of such effects can be traced to the embodied cognition framework in which abstract meanings are accounted for in terms of concrete bodily interactions (Barsalou, 1999; Lakoff & Johnson, 1980, 1999; Van Rompay & Ludden, 2015; Van Rompay, Hekkert, Saakes, & Russo, 2005). For instance, aforementioned finding that shape angularity results in a more intense taste experience (Becker et al., 2011) can be traced to object interactions in which we find that angular and sharp form features (as opposed to smooth and organic form features) generate a more forceful impression on our skin. Consequently, these tactile sensations may transfer to taste, resulting in a more intense taste experience and heightened evaluations on related taste characteristics such as *bitterness* (Van Rompay et al., 2017), and (in line with the notion that different sense sensations may share the dimension of intensity; Boring, 1942) arguably also *sourness* (likewise experienced as 'intense').

2.1. Congruence and food liking

Apart from showing that look-and-feel aspects of packaging design may impact basic taste sensations, when it comes to taste liking and product liking, findings suggest that appropriateness of surface texture vis-a-vis a specific drink type should be considered. In Van Rompay et al. (2017), overall evaluations were positively affected by a match between drink type and surface texture (e.g., sweet tea in a sample cup with rounded elements), rather than a mismatch (e.g., sweet tea in a sample cup with angular elements).

To better understand this latter type of congruence effects, the processing fluency framework is of particular interest (Reber, Schwarz, & Winkielman, 2004; Van Rompay & Pruyn, 2011; Van Rompay, Pruyn, & Tieke, 2009). According to this account, stimuli that can be easily processed are liked better (because fluent processing indicates that things in the environment pose no danger or cognitive challenges; Lee & Labroo, 2004; Reber, et al., 2004). Importantly, congruence may facilitate processing. That is, when confronted with different stimuli (such as a packaging design and a promotional poster for the same product), consumers face the task of integrating meanings connoted across these elements into an overall impression. Mixed signals may elicit ambiguity with respect to product identity, thereby negatively affecting subsequent product evaluations.

On the other hand, studies from advertising research indicate that information incongruences may also be used as a means to attract attention, boost recall of ad elements, and enhance product and brand evaluations (Heckler & Childers, 1992; Lee & Mason, 1999; Maheswaran & Chaiken, 1991; Meyers-Levy & Tybout, 1989). For instance, Heckler and Childers (1992) demonstrated positive effects of meaning incongruence on memory for advertising elements, indicating that incongruence may prompt elaborate processing by presenting something unexpected or a 'puzzle' to be solved. In line with this latter notion, studies in emotion psychology and design research show that incongruences may evoke positive emotions (Ludden, Schifferstein, & Hekkert, 2009, 2012; Silvia, 2005a, 2005b). For instance, Ludden, Schifferstein, et al. (2012) showed that products triggered surprise when expectations generated by their visual appearance were disconfirmed during subsequent (multisensory) product interactions.

These combined findings suggest that stimulus congruence may give rise to positive product evaluations by facilitating processing, but that incongruence may positively impact consumer response by presenting something new or unexpected that encourages stimulus processing (and may therefore enhance product liking). In order to test the merits of both accounts in the context of the current research, we will study the interplay between surface textures (distinguishing between a sharp and a smooth surface) and visual representations of sharp or smooth elements on a promotional poster for the same product.

Based on the foregoing we expect that a sharp impression (either conveyed through surface texture or shape) transfers to related taste sensations (i.e., tastes experienced as 'intense'), in this research *sourness* in particular. Furthermore, based on previous research (e.g., Ngo et al., 2011; Stewart & Goss, 2013), we expect that smooth, rounded stimuli (embedded in surface texture or poster design) enhance evaluations of sweetness. Hence:

H1. A sharp, versus smooth, surface texture or poster design results in a *sourer* and *less sweet* taste experience, and vice versa.

H2. A sharp, versus smooth, surface texture or poster design results in an overall *more intense* taste experience.

With respect to taste and product liking, it is expected that a match between surface texture and ice-cream variant (i.e., a sweet and smooth vanilla variant versus a sour and sharp lemon variant) boosts evaluations such that:

H3. A sharp (versus smooth) surface texture in combination with a fitting (rather than a non-fitting) sour ice cream variant enhances taste and product liking, and vice versa.

In addition to these hypotheses, we will thus also address the more explorative research question how a match or mismatch between 3D-printed surfaces and corresponding shapes on a poster influence taste and product evaluation.

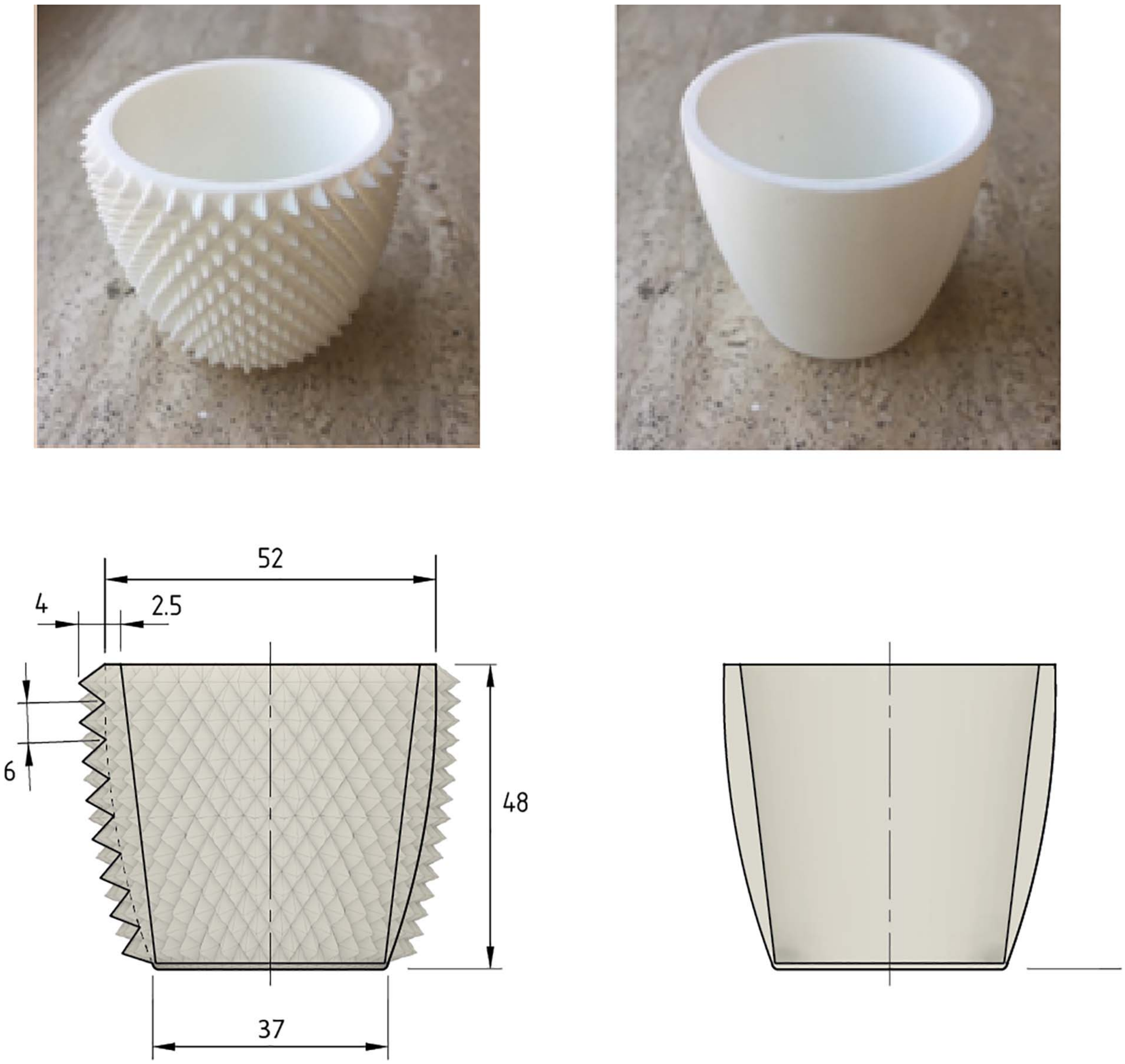

Fig. 1. Sample cups (top) and corresponding renderings (bottom). *Note:* measures are presented in millimeters.

To test these predictions and explorative research question, 3D printed cups with either a sharp or smooth surface were fabricated and used as sample containers for either a sweet vanilla ice cream or a sour lemon variant. During the taste session, a poster was hanging down either presenting sharp or smooth shapes. Hence, a 2 (surface texture: sharp versus smooth) X 2 (ice-cream type: vanilla ice cream versus lemon ice cream) X 2 (visual poster design: sharp versus smooth shapes) between-subjects design was employed.

3. Method

3.1. Materials

3.1.1. Sample cups

A set of two cups with either a sharp, spikey surface texture or a smooth, even surface (selected after informal presentation of a larger series of sample cups to participants) was 3D-printed, resulting in either a very sharp-feeling sample cup or a very smooth-feeling sample cup (see Fig. 1). The stimuli were manufactured from polylactic acid with a Fused Deposition Modelling (FDM) 3-D printer. The printer, an Ultimaker 2, allowed for the creation of highly detailed and accurate (100 µm) customizable models.

Specifically, the cups have a height of 48 mm, a diameter of 52 mm at the top, 37 mm at the bottom, and a wall thickness of 2.5 mm. The “sharp cup” is patterned with rhombic pyramids (spikes) that protrude 4 mm outwards from the surface. We distributed 8 pyramids vertically and 38 horizontally around the cup. Each is 6 mm high and the width varies with the diameter of the cup (ranging from 4.2 mm at the top to 3.2 mm at the bottom). These printed models fit as a sleeve around a small paper (sample) cup (replaced per subject for hygienic purposes).

3.1.2. Poster designs

In order to decide on the appropriate poster design, a set of four posters, each presenting either sharp or smooth shapes (i.e., eight posters in total), were presented to 17 participants who rated the poster designs on the extent to which they were considered fitting the verbal labels ‘sweet’ and ‘sour’ (while also taking into account realism and liking). In Fig. 2 the finalized poster designs are presented.

3.2. Participants and procedure

The field experiment took place in a separated area in a Dutch ice-cream salon. In total, 176 customers (112 female and 64 male participants, age range: 14–60 years) participated in the experiment. An

Fig. 2. Finalized poster designs. *Note:* "Ijsje proeven?" translates as "Wanna try ice cream?"

analysis of variance confirmed that gender and age were equally distributed among the conditions (i.e., in both cases $F < 1$).

Participants were all customers visiting the salon to enjoy an ice cream on a summer day (all data were collected in one week on days with similar [sunny and warm] weather conditions). They were approached upon entering or while waiting in line and asked if they would be willing to participate in a short ice-cream taste test. Upon agreement, they were guided to the tasting area and the taste test was introduced. In doing so, the poster was pointed out (ensuring that all participants were exposed to the poster design manipulation), which was hanging down the wall (printed in A2 format) right in front of the participant.

Subsequently, they were handed either a teaspoon-sized scoop of 'homemade' dairy-based vanilla ice cream or sorbet (dairy-free) lemon ice-cream flavor (temperature: −20 °C), for hygienic purposes served in a small (38 ml/1.25 oz) paper sampling cup slid into the 3D-printed sharp or smooth container. As such, it was ensured that all participants actually interacted with the sample cups (and hence were exposed to the surface texture manipulation). Next, they tasted the ice-cream after which they filled out the survey comprising the dependent measures. After completion, participants were thanked for their participation and, if interested, informed about the study.

3.3. Measures

As participants were actual customers, only spending a limited amount of time in the ice-cream salon, for practical reasons, a brief questionnaire (comprising the dependent measures) was used.

3.3.1. Taste evaluation measures

Participants first rated (using 7-point rating scales), the ice creams on perceived *sweetness* and *sourness*. Specifically, they had to indicate to what extent these two items applied to ice-cream taste (scale anchors: not at all, very much so).

Taste intensity was measured with the items *sharp*, *strong* and *intense* (alpha = 0.76). Again, participants rated to what extent these items applied to ice cream taste. Taste liking was measured with the statement "*I like the taste of the ice-cream*". Finally, taste expectancy was measured with the items "*The ice-cream tasted exactly as I expected*" and "*I am surprised about the taste of this ice-cream* (reverse-coded)" (alpha = 0.77).

3.3.2. Overall product evaluation

Finally, the overall liking of the product trial was measured using four items (based on Hirschman and Solomon's [1984] brand evaluation scale); '*I feel positive about this product*', '*I like this product*', '*This product pleases me*', and '*This an attractive product*' (alpha = 0.90). (*Note:* taste liking and overall product evaluation were significantly correlated, $r = 0.70$, $p < 0.01$).

4. Results

4.1. Basic taste evaluation: sweet

An ANOVA with texture (smooth versus sharp surface), poster design (smooth versus sharp shapes), and flavour (vanilla versus lemon) as independent variables and taste sweetness as dependent variable revealed a main effect of ice-cream flavour (F (1.168) = 88.97, $p < 0.001$, $\eta^2 = 0.35$), showing that vanilla was, as expected, perceived as significantly sweeter than the lemon ice-cream ($M = 5.80$, $SD = 0.96$, versus $M = 3.94$, $SD = 1.63$).

More interestingly, the ANOVA also showed a significant main effect of texture (F (1.168) = 10.13, $p = 0.002$, $\eta^2 = 0.06$) showing (in line with predictions) that the smooth, as opposed to the sharp, surface enhanced perceived sweetness ($M = 5.18$, $SD = 1.59$, versus $M = 4.56$, $SD = 1.60$).

The main effect of poster design was not significant (F (1.168) = 1.77, $p = 0.19$, $\eta^2 = 0.01$), neither were the interaction effects (flavour × texture: $F < 1$, *ns*; flavour × poster design: $F < 1$, *ns*; texture × poster design: $F < 1$, *ns*; flavour × texture × poster design: F (1.168) = 2.82, $p = 0.10$, $\eta^2 = 0.16$).

4.2. Basic taste evaluation: sour

For taste sourness, an ANOVA likewise revealed a main effect of flavour (F (1.168) = 1261.27, $p < 0.001$, $\eta^2 = 0.88$), showing that lemon was, as expected, perceived as significantly sourer than vanilla ice cream ($M = 6.23$, $SD = 0.74$, versus $M = 1.63$, $SD = 1.00$).

However, this time the main effect of texture was (although in the predicted direction) not significant (F (1.168) = 2.78, $p = 0.10$, $\eta^2 = 0.02$). Likewise, the main effect of poster design was not significant ($F < 1$, *ns*). However, the interaction between flavour × poster design *was* significant (F (1.168) = 8.37, $p < 0.01$, $\eta^2 = 0.05$; see Fig. 3), showing that vanilla was perceived as significantly ($p = 0.01$) sourer in the sharp poster design condition compared to the smooth poster design condition ($M = 1.86$, $SD = 1.13$, versus $M = 1.39$, $SD = 0.78$). For lemon, this difference was not significant ($p = 0.14$). No other interaction effects reached significance (all F's < 1, *ns*)

4.3. Taste intensity

An ANOVA with 'taste intensity' as dependent variable showed a main effect of ice-cream flavor (F (1.168) = 63.48, $p < 0.001$, $\eta^2 = 0.27$), showing that lemon was indeed perceived as stronger in taste than vanilla ($M = 4.70$, $SD = 1.05$, versus $M = 3.46$, $SD = 1.09$). More interestingly, a main effect of texture surfaced (F (1.168) = 6.88,

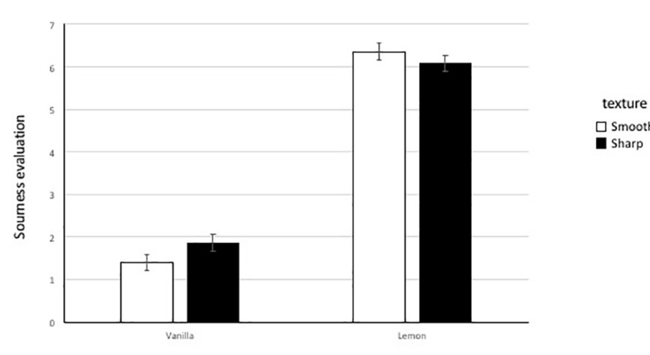

Fig. 3. Interaction effect between flavor and poster design on sourness evaluation.

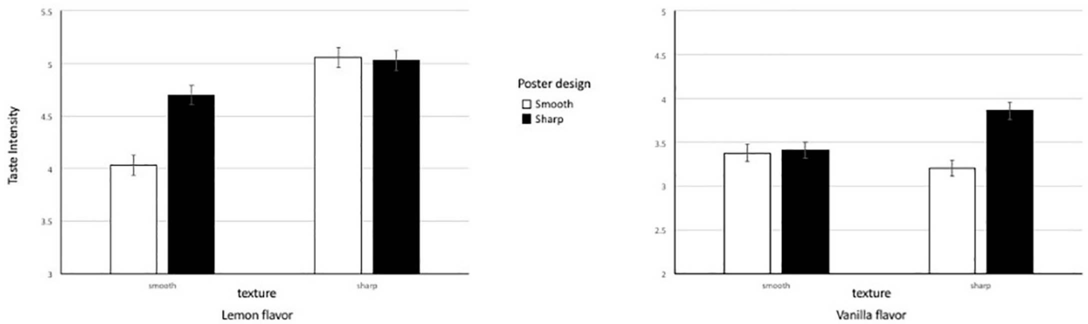

Fig. 4. Three-way interaction between flavor, texture and poster design on taste intensity.

$p = 0.01$, $\eta^2 = 0.04$), showing that (regardless of ice cream flavor) the sharp, as opposed to the smooth, surface enhanced perceived taste intensity ($M = 4.29$, $SD = 1.30$, versus $M = 3.88$, $SD = 1.14$).

This time, the main effect of poster design was also significant (F (1.168) = 4.57, $p = 0.03$, $\eta^2 = 0.03$), indicating that the poster with sharp shapes, as opposed to smooth shapes, enhanced perceived taste intensity ($M = 4.25$, $SD = 1.12$, versus $M = 3.92$, $SD = 1.35$). Furthermore, the three-way interaction between flavor, texture, and poster design reached significance (F (1.168) = 4.57, $p = 0.03$, $\eta^2 = 0.03$; see Fig. 4). Specifically, when tasting lemon (left panel) from the congruent sharp cup, poster design had no effect on perceived taste intensity (F < 1, ns). However, when participants tasted the lemon ice-cream from the incongruent smooth cup, the angular (as opposed to the rounded) poster resulted in higher taste intensity evaluations (M = 4.70, SD = 0.81, versus M = 4.03, SD = 1.09, p < .01).

As for vanilla (right panel); when the ice-cream was tasted from the congruent smooth cup, the effect of poster design was not significant (F < 1, ns). However, when participants tried the vanilla ice-cream from the (incongruent) sharp cup, the effect of poster on taste intensity was significant ($p < .01$). Also in this case, the poster presenting sharp shapes led to a significantly higher evaluation of perceived taste intensity as opposed to the poster with smooth shapes ($M = 3.86$, $SD = 1.10$, versus $M = 3.20$, $SD = 1.08$).

4.4. Taste liking

An ANOVA with taste liking as the dependent variable showed no main effect of flavour ($F < 1$, ns), indicating that there was no preference for either one of the ice cream variants. The main effect of texture was not significant (F (1.168) = 1.24, $p = 0.27$, $\eta^2 = 0.01$), neither was the main effect of poster design ($F < 1$, ns).

However, the interaction effect between texture × poster design was significant (F (1.168) = 5.54, $p = 0.02$, $\eta^2 = 0.03$; see Fig. 5), showing that within the 'sharp' texture condition, the smooth poster design enhanced taste liking (M = 6.07, SD = 1.11, versus M = 5.43, SD = 1.30). For the smooth surface, the pattern is reversed, however the difference between poster variants here is not significant ($F < 1$, ns).

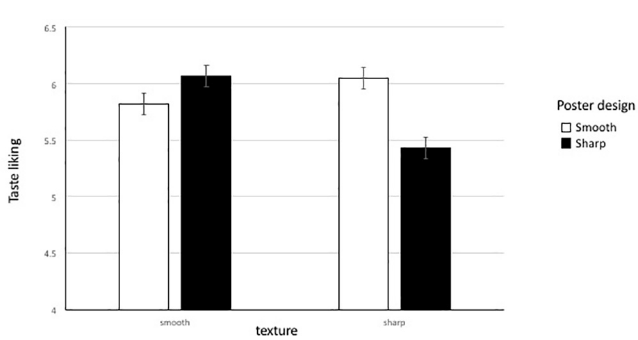

Fig. 5. Interaction between texture and poster design on taste liking.

4.5. Taste expectancy

An ANOVA with taste expectancy as the dependent variable showed a main effect of ice-cream flavor (F (1.168) = 8.47, $p = 0.004$, $\eta^2 = 0.05$), indicating that vanilla tasted more 'expected' than lemon (M = 4.84, SD = 1.30, versus M = 4.26, SD = 1.34). The main effects of texture and poster design were not significant (all F's < 1, ns).

Interestingly, the interaction between flavor and texture was significant (F (1.168) = 4.46, p = 0.04, $\eta^2 = 0.03$; see Fig. 6), suggesting that the vanilla variant tasted more 'as expected' (and hence as less surprising) when sampled from the smooth cup, whereas the lemon variant tasted more 'as expected' when sampled from the sharp cup. However, pairwise comparisons indicate that for both flavors, these differences between the sample cups were not significant (both p's > 0.10). No other interaction effects were obtained (all F's < 1, ns).

4.6. Overall product evaluation

In line with the results for taste liking, an ANOVA with overall product liking as dependent variable showed no main effect of ice-cream flavour, texture and poster design (all F's < 1, *ns*).

Again, and in line with taste liking, the interaction effect of texture x poster design was significant (F (1.168) = 4.16, $p < .05$, $\eta^2 = 0.02$; see Fig. 7). Similar to the results for taste liking, within the 'sharp' poster design condition, the smooth cup inspires more favourable evaluations ($M = 5.71$, $SD = 0.96$, versus $M = 5.30$, $SD = 0.84$; F (1.168) = 3.66, $p = 0.06$, $\eta^2 = 0.02$). Within the 'smooth' poster design condition, this difference was not significant ($F < 1$, *ns*). No other interaction effects were obtained (all F's < 1, *ns*).

5. General discussion

The findings reported show that surface textures may influence taste evaluation. Specifically, a smooth surface resulted in a sweeter taste

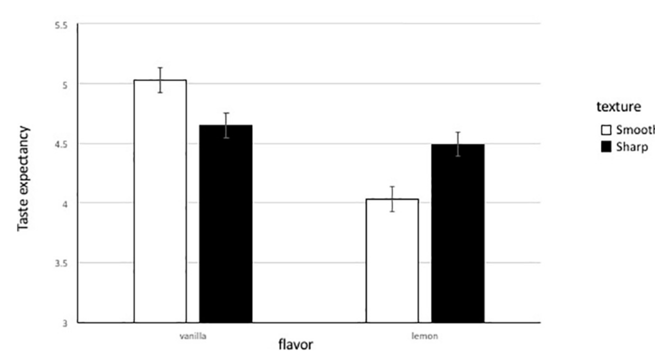

Fig. 6. Interaction between texture and flavour on taste expectancy.

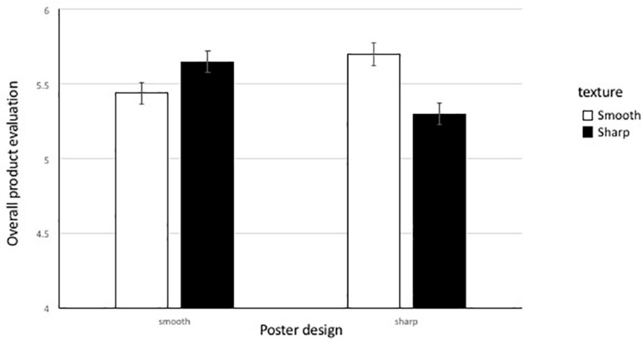

Fig. 7. Interaction between texture and poster design on overall product evaluation.

experience, whereas a sharp surface inspired a (marginally) sourer taste experience. Furthermore, and in line with previous research (Van Rompay et al., 2017), the sharp cup inspired a more intense taste sensation compared to the smooth cup. No main effects of poster design were observed, except for its effects on taste intensity, showing (in line with Becker et al., 2011) that sharp, angular shapes enhance taste strength. Finally, incongruence between texture and poster design heightened taste and product liking. These findings clearly stress the feasibility of shaping specific taste sensations and enhancing food experiences through the interplay of surface textures and poster design.

Admittedly, the interactive effects (suggesting that incongruence between poster and cup may enhance taste and product liking) were, although showing the same pattern for both measures, relatively weak (as evidenced by follow-up pairwise comparisons). Clearly, follow-up research is needed to further confirm and unravel these findings. As discussed, research suggests that (moderate) incongruence might be evaluated positively as it can trigger surprise, curiosity, or heighten attention (e.g., Berlyne, 1971; Ludden et al., 2009; Meyers-Levy & Tybout, 1989). For instance, Meyers-Levy and Tybout (1989) showed that moderate incongruences (e.g., a soft drink description that includes an attribute not associated with a typical soft drink such as 'all-natural') may positively influence product evaluation as long as it can be made sense of (i.e., integrated in the schema for soft drinks). Findings from emotion psychology and design research likewise suggest that incongruences may foremost result in positive consumer response when the incongruence encountered can be made sense of (Ludden, Kudrowitz, Schifferstein, & Hekkert, 2012; Silvia, 2005a, 2005b). Of particular relevance, our findings are in line with Ludden, Kudrowitz, et al. (2012), who demonstrated enhanced liking for products presenting visual-tactile incongruences.

Arguably, incongruences created through design factors are subtler (and hence more easily 'resolved') compared to incongruences exemplified by slogans (as used in Van Rompay et al., 2017). One way to understand this difference is to distinguish between consumer-generated impressions generated by visual design cues (such as the shapes in the present study) and meanings enforced through slogans or claims (Krishna, 2012). Arguably, the incongruences between surface texture and shape (which customers in our study were faced with) were not interpreted as 'false' or 'mistaken' but could be reconciled (e.g., perhaps by describing ice cream taste as 'a smooth ice cream with a distinctive touch'; cf. Meyers-Levy & Tybout, 1989). Note that such flexibility or freedom of interpretation is not provided by slogans specifically highlighting taste attributes (such as taste strength). Further stressing the relatively 'subtle' impact of design cues, Becker et al. (2011) showed that effects of shape angularity were only significant for people with a high sensitivity to design (Bloch, Brunel, & Arnold, 2003). Perhaps then, our explicit taste expectancy measure was perhaps too 'extreme' (as these might reflect more distinct or emotionally-charged experiences) in order to capture relatively subtle design effects.

6.1. Limitations

The findings presented do not allow for assessments on the relative contributions of visual and tactile sensations to taste evaluation. That is, participants first saw the poster and sample cup and were then handed the respective cup for the taste trial. Although, visual exposure to the sample cups could be prevented (e.g., by blindfolding participants), in our study this was not feasible as visual access was necessary to allow for poster perception. Furthermore, by involving customers in an actual ice-cream tasting session, taking place at an ice salon, ecological validity of our findings is high. Regardless, more controlled lab studies are warranted to confirm the validity of our findings, and also in order to gain control over potential confounds (e.g., noise and presence of other customers walking in or waiting in line), which may have influenced the extent to which participants could pay sustained attention to, for instance, poster design.

Furthermore, although our findings suggest that incongruences between surface texture and poster design may positively impact product and taste evaluations, follow-up analyses of interaction effects do not warrant strong conclusions. For instance, incongruence between surface texture and poster design only resulted in improved liking in the sharp texture condition, whereas differences (between shape design) in the smooth surface condition did not reach significance. Arguably, incongruence between surface texture and poster design was more apparent in the sharp surface condition where (as indicated by the main effect of surface texture on taste intensity) sensations were experienced as more intense or extreme (compared to the smooth surface condition). For this same reason, we can also not rule out that interactions with the cups differed in terms of pleasure or comfort. Finally, it should be acknowledged that although the smooth cup came out as the smoothest variant in informal pretesting preceding this study, it does not contain a surface pattern, whereas the sharp cup clearly does (as illustrated in Fig. 1). This difference in cups might have introduced additional variations in terms of, for instance, complexity or typicality perceptions.

Regardless of these shortcomings, as costs associated with 3D printing will continue to drop in the years to come, and the quest for differentiation and a unique positioning in the marketplace will continue, certainly 3D printing applications in this sector (ranging from plateware in restaurants, to product packaging in supermarkets, to the types of containers or cups used in café's and ice salons) will continue to grow. Furthermore, considering the feasibility of systematically varying 3D textures (ranging from very subtle surface textures to more extreme patterns), clearly opportunities for experimental research in which such 'new' tactile factors are combined with equally advanced means for product promotion in consumption and retail environments abound.

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