Cup texture influences taste and tactile judgments in the evaluation of specialty coffee

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Abstract

It has been demonstrated previously that the surface textures of product packaging and servingware can impact the perceived taste and mouthfeel of various different foods and beverages. The present study was designed to investigate whether coffee cups with different surface textures would influence the judgment of taste and mouthfeel attributes in specialty coffee by experts (Q-graders) and amateur consumers alike. A total of 231 participants were tested in one of the three studies. A preliminary test conducted at a specialty coffee event in Russia indicated that rubbing a swatch of sandpaper whilst drinking coffee influenced perceived body and aftertaste qualities. In the two main studies (Experiment 1 for Q-graders, and Experiment 2 for amateurs), the participants evaluated a sample of specialty coffee (a different coffee in each study) served in either a smooth or a rough ceramic cup. The coffee was rated by the Q-graders as tasting significantly more acidic when sampled from the rough cup, as opposed to the smooth, whereas the amateurs perceived the coffee as being significantly sweeter when tasted from the smooth cup rather than from the rough cup instead. Both Q-graders and amateurs judged the aftertaste as significantly dryer when tasted from the rough rather than from the smooth cup. The perception of body was not significantly affected in any of the experiments. These results demonstrate that haptic cues influence the judgment of basic tastes as well as mouthfeel attributes in specialty coffee, for both experts and amateur consumers. Such results should be considered by the industry when designing innovative coatings for coffee cups. In addition to innovation, though, it is important to create cups that convey some functional and/or perceptual benefit for the coffee drinking experience.

KEYWORDS: Specialty coffee; Cup texture; Somatosensory perception; Taste; Crossmodality; Sandpaper.

1. Introduction

Although most research on multisensory flavour perception has focused on the contribution of chemosensory stimuli, a steady stream of experimental studies have demonstrated that the physical attributes of what we eat and drink are also constitutive of our flavour experiences (e.g., Bult, de Wijk, & Hummel, 2007; Green, 2002; Slocombe, Carmichael, & Simner, 2016). Physical stimuli are encoded by the oral-somatosensory receptors and contribute to the tactile experience (or mouthfeel) of what we consume, which includes perception of texture (e.g., viscosity, brittleness) and temperature (see Spence & Piqueras-Fiszman, 2016, for a review). In addition to the oral-tactile experience yielded by the food or beverage itself, several studies have shown that the haptically-perceived[1] tactile properties of the food affect the judgment of several taste/flavour attributes (Barnett-Cowan, 2010; Mobini, Platts, & Booth, 2011; Slocombe et al., 2016). What is more, product-extrinsic haptic information from packaging materials and servingware can also influence flavour and hedonic evaluation of food and beverages (Krishna & Morrin, 2008; Piqueras-Fiszman, Harrar, Alcaide, & Spence, 2011; Maggioni, Risso, Olivero, & Gallace, 2015; Wang & Spence, 2018; see Spence, 2019a, for a review).

One salient product-extrinsic haptic attribute is the outer surface texture of the food or drink container from which the drink is consumed (Biggs, Juravle, & Spence, 2016; Piqueras-Fiszman & Spence, 2012; Van Rompay, Finger, Saakes, & Fenko, 2017). For instance, Piqueras-Fiszman & Spence (2012) demonstrated that participants rated digestive biscuits served from a container with a rough surface texture as both crunchier and harder than biscuits tasted from the smooth container instead. Intriguingly, though, when yoghurt samples were tasted from the exact same pair of containers, no significant effects on ratings were found. This study demonstrated that the feel of the container influenced people's perception of a dry food product, and the null results on yoghurt ratings suggest that there may be limitations on the conditions (e.g., food attributes, serving context) under which haptic cues influence flavour perception. In the same way, Slocombe et al. (2016) failed to observe a significant effect of a rough versus smooth serving plate on the perception of sweetness, bitterness, and acidity of lemon curd. Despite the lack of an effect of the serving plate, the rough/smoothness coating of the foodstuff itself was, though, shown to significantly influence basic taste ratings. Once again, null results raise caution against an over-reliance on

[1] Haptics refers to active touch, or tactile qualities experienced by the hands.

relative effects when considering practical applications. Thus, instead of generalizing relative to broader influences, it is important to test whether the tactile/haptic attributes of the container would impact flavour attributes of specific products.

Meanwhile, research by Biggs et al. (2016) demonstrated that caramelised biscuits taken from a plate with a rough surface were rated as tasting crunchier and rougher than when the same biscuits were served on a smooth and shiny plate instead. In a second experiment, the participants rated both biscuits and jelly-babies from the same two plates. The findings with respect to the biscuits were replicated, while the jelly babies were rated as chewier when served on the rough plate as compared to the smooth plate. These results at least hint at the possibility that the rough feel of the plate could have primed the dominant textural property of the food itself, namely, crunchiness for biscuits and chewiness in the case of jelly babies.

In another study, Van Rompay, Kramera, and Saakes (2018) used 3D-printed patterns to deliver different macrogeometric textures in the outer surface of eating receptacles. The participants tasted vanilla or lemon ice-cream from cups having either an angular or smooth 3D-printed texture. Once again, the texture of the receptacle was shown to influence the tasting experience. The angular surface pattern, as opposed to the smooth, decreased perceived sweetness (with no significant effect on acidity ratings, though) as well as increased flavour intensity of the ice-creams. Recently, it has been shown that impact of rough (vs. smooth) bowls impacted the perceived saltiness of crisps, with ratings found to be dependent on the level of saltiness of the tasted crisps (Van Rompay & Groothedde, 2019).

Despite a large number of studies showing that haptic properties of the container from which the food happens to be consumed impact consumers’ judgments of the food product itself, there has been little research on this effect as far as beverages are concerned. One early study (Schifferstein, 2009) asked the participants to evaluate the experience of consuming either hot Earl Grey tea or a chilled lemon soft drink from cups made of different materials (glass, ceramic, opaque plastic, partly translucent plastic, and melamine). The different cups significantly affected the judgements of sensory attributes ‘warmth’ and ‘sweetness’, but since they varied in other characteristics such as colour and weight as well as texture, the differences between cups cannot be attributed to differences in material (or texture) properties alone.

Another study had the participants evaluating brewed coffee or hot chocolate that was served in a cup that had a rounded or more angular macrogeometric 3D-printed texture (Van

Rompay et al., 2017). In this case, the results revealed that the texture affected the evaluation of taste qualities of the beverages. In particular, the coffee and the hot chocolate were rated as tasting less intense and sweeter when sampled from the round textured cup whereas the angular textured cup enhanced the perceived intensity of the taste and bitterness ratings of both beverages. A second study tested the impact of touching a swatch of velvet or sandpaper on the wine-tasting experience (Wang & Spence, 2018). The results of a first study revealed that the velvet enhanced the perceived sweetness of a white wine when compared to the sandpaper. In a second study, a red wine was rated as having a fruitier aroma, and as tasting sweeter and more pleasant when the participants were instructed to touch velvet rather than sandpaper. More recently, Risso, Maggioni, and Gallace (2019) had blindfolded participants to rate the freshness, pleasantness, carbonation, and lightness of still or carbonated mineral water. The water was served in cup with one of three different textures -- plastic cups covered with sandpaper or satin, or without any cover (i.e., plastic texture). Both types of water were rated as being more pleasant, fresher, and lighter when tasted from the plastic cups as compared to cups covered with sandpaper or satin, and the intensity of carbonation was not modulated by the different cup textures.

The three studies mentioned above demonstrate that the texture felt in the hand can affect judgments of taste (i.e., gustatory) attributes and flavour intensity of beverages. However, despite the independent variable in both studies being the haptic attribute, its effect on oral-somatosensory properties of the beverages, namely, mouthfeel/body and aftertaste[2], would seem to have been overlooked. In fact, the concept of sensation transference (see Cheskin, 1972) is a key notion when it comes to understanding how the haptic information may impact the judgment of the food product itself. 'Sensation transference' refers to the observable effect of having the consumers' (conscious or otherwise) expectations or feelings about the food receptacle being transferred to their ratings of the food or beverage itself. In other words, relevant product-extrinsic cues can be carried over to influence the consumers' evaluation, and presumably also their experience, of the properties of the product as well. Thus, if the haptic properties of the container – such as its texture – are manipulated, it is

[2] Aftertaste is defined as flavour impressions that are left on the palate after swallowing, and it can be described in terms of quality, intensity, and duration (Lawless & Heymann, 2010). Description of aftertaste relies heavily on the use of terms for taste qualities (i.e., sweet, sour/acidic, salty, bitter, umami) as well as tactile sensations such as tingling and viscous. Despite residual mouthfeel effects being included under the general term afterfeel (see Guinard & Mazzucchelli, 1996), in the present study, we refer to lingering mouthfeel qualities (i.e., dryness or smoothness) as aftertaste, meaning an overall residual flavour (see Phillips, McGiff, Barbano, & Lawless, 1995; Porubcan & Vickers, 2005).

plausible to infer some kind of effect on the ratings of oral-somatosensory attributes of the product tested, be it a food or a beverage.

Parallel to the research on the impact of haptic cues on multisensory flavour experience, a number of companies have focused on giving their packaging/servingware a distinctive feel, seemingly as a strategy to stand out from the competition (see Gallace & Spence, 2014, and Spence, 2019a), sometimes seemingly without considering the effect of the haptic container on the consumer's multisensory product experience (Skaczkowski, Durkin, Kashima, & Wakefield, 2016). In recent years, the impressive rise of the specialty coffee industry has undoubtedly opened up discussion about new ways of presenting coffee to the consumer.

Specialty coffee is a term that is used to refer to those coffees that can be distinguished on the basis of quality and uniqueness of origin, according to the Specialty Coffee Association (SCA) and the international Q Coffee System protocols (Lingle & Menon, 2017). Similar to wine, specialty coffee is undoubtedly a chemically/perceptually very complex beverage regarding (1) the number of volatile aromatic compounds and (2) combinations of volatiles yielding different flavours than those expected from individual compounds (Chambers & Koppel, 2013; Rhinehart, 2009). In fact, whilst wine has been estimated to contain 600-1,000 volatile aromatic compounds (Rapp, 1990; Tao & Li, 2009), something like 1,200 volatiles have been reported in coffee (Clarke, 2013; Yeretzian, 2017; though see also Spence & Wang, 2018, on the complex notion of complexity as far as the chemical senses are concerned). Additionally, as a function of their status as agricultural products that are processed after harvesting, wine and coffee can reach a huge variation of distinctive characteristics in terms of their body, aroma, and flavour complexity (Schwan, Silva, & Batista, 2012; Styger, Prior, & Bauer, 2011). The cup in which the coffee is served is increasingly coming to be considered as an essential element in terms of turning the consumption of specialty coffee into a truly engaging multisensory experience (Carvalho & Spence, 2018, 2019). Indeed, there has been growing interest amongst quality coffee brands and certain ceramic/porcelain companies in developing signature coffee cups (see Spence & Carvalho, 2019, for a review). This distinctiveness includes changes in the haptic attributes of the drinking vessel, such as variations in terms of shape, weight, and texture (by varying material or finish). A few examples should be sufficient to illustrate the point. Take, for example, the 'Nespresso Touch Collection' with a soft touch ring (Schuch, 2018), the weight of 'Acme & Co' espresso cups (Ferst, 2016), or the uniquely-shaped 'Figgjo Oslo – Tim Wendelboe' made of smooth porcelain (as tested by Carvalho & Spence, 2018). The

‘Loveramics Brewers’ cups are made of ceramic and have a distinctively rough finish[3]. In fact, even reusable takeaway coffee cups are now being reinvented in a range of materials, colours, and different textures (Agate, 2019). Despite the claims often made by the cup manufactures regarding rather specific effects of cups on the specialty coffee drinking experience, empirical evidence supporting such claims thus far remains noticeably absent.

The goal of the present research was therefore to evaluate the influence of external tactile feedback on the specialty coffee tasting experience. Specifically, we wanted to extend Wang and Spence’s (2018) results with wine by testing whether rough versus smooth textures would affect people’s judgments of aroma, sweetness, acidity, and mouthfeel in specialty coffee. Moreover, we deepened the investigation concerning the oral-somatosensory domain by assessing the effects of texture on aftertaste in addition to mouthfeel/body, which were rated in terms of smoothness or dry/roughness. Drawing upon the aforementioned notion of ‘sensation transference’, it was hypothesised that surface texture may impact the perceived mouthfeel and aftertaste of specialty coffee. We also expected to replicate previous findings (Van Rompay et al., 2017; Wang & Spence, 2018) by demonstrating that a smooth surface texture can enhance sweetness ratings in comparison to a rougher surface texture. Furthermore, both specialty coffee experts and amateur consumers were tested in two separate experiments. Swatches of sandpaper were used in the preliminary study, and the two main experiments involved a naturalistic approach by manipulating the texture of the coffee cups themselves.

2. Methods

2.1. Participants

A total of 231 participants gave their informed consent to take part in one of the three studies reported in the present study. The study was approved by the Research Ethics Committee of the School of Psychology, University of São Paulo, Brazil. After data quality control, the data from 31 participants were included in the final analysis of the preliminary study (11 female; age: 33.1 ± 7.8, 21 to 54 years-old), 81 in the final analysis of Experiment 1 (38 female; age: 35.5 ± 5.5, 25 to 51 years-old), and 117 in the final analysis of Experiment 2 (59 female; age: 33.4 ± 8.5, 19 to 65 years-old).

[3] https://www.loveramics.com/collections/brewers.

2.2. Stimuli

2.2.1. Coffee

Only single origin Arabica coffees were used in the experiments reported here. All of the coffees were assessed by SCA-certified sensory analysts (i.e., Q grader cuppers)[4]. In all three studies, the participants were only served one type of coffee. The coffee used in the preliminary study came from the region of Sipi Falls, Uganda (altitude of 1300–2000m). The cultivars were SL14 and SL28, and the post-harvest processing method used was dry/natural (Schwan, Silva, & Batista, 2012). The coffee sample received an overall score of 86 points on a 0-100 scale (Lingle & Menon, 2017), with high sweetness and acidity. Regarding overall aroma/flavour characteristics, the coffee was described as having strong notes of stone fruits and caramel. It is important to point out that the term 'acidic' has been used instead of 'sour' to refer to the taste quality because the specialty coffee industry has adopted the term acidity in reference to the sour basic taste in their official sensory evaluation protocol. Moreover, saying that a specialty coffee is high or low in a certain taste (i.e., sweetness, acidity) or tactile (i.e., body, astringency) attribute is comparative or related to the average over specialty coffees. As such, it is similar to refer to red wines as high or low in tannin content.

The coffee used in Experiment 1 came from Luisburgo, Minas Gerais, Brazil (Matas de Minas region; altitude of 1160m). The cultivar was Yellow Catuai and was also processed as natural. The coffee sample was given an overall score of 87 points, with high sweetness and low-to-medium acidity. The coffee aroma/flavour attributes were described as having predominant fruity and floral notes.

For Experiment 2, the coffee served was from the Recanto Estate, located in Machado, Minas Gerais, Brazil (Sul de Minas region; altitude of 1100m). The cultivar was Yellow Bourbon processed as natural coffee, with an overall score of 86 points, with high sweetness and

[4] A Q grader is an individual who is credentialed by the Coffee Quality Institute (CQI) to grade and score coffees utilizing standards developed by the SCA. In this evaluation, grades on a hedonic/quality scale of six to ten (anchors: 6-Good, 7-Very good, 8-Excellent, 9-Outstanding) are awarded for the attributes of fragrance/aroma, sweetness, acidity, body, flavour, balance, and aftertaste. Cuppers also assess the quality attributes 'clean cup', 'uniformity', and 'overall' awarding points per cup. Each attribute worth 10 points, so that evaluations would be based on a 100-point scale. For more details on the cupping protocol, please see Lingle & Menon (2017). It is important to mention that dominant bitterness and astringency are negative attributes, and classified as primary defects. Specialty coffees are those coffees with a cupping score of 80 or more points and with no primary defects.

medium acidity. The predominant coffee aroma/flavour notes were fruity (red berries and stone fruits) and winey.

In all three studies, the coffee beverage served to the participants was a brewed (pour-over) coffee. For the preliminary study, the coffee was brewed using a Marco Brewer (Marco Beverage Systems, Dublin, Ireland) at a concentration of 60 g·L−1. For Experiment 1, the coffee was prepared using the Bunn-O-Matic ICBA (BUNN, Springfield, USA) at a concentration of 58 g·L−1. Finally, for Experiment 2, the coffee was brewed using the Hario V60 Kit (Hario V60; Tokyo, Japan) at a concentration of 66 g·L−1. For all preparations, mineral water at 92 °C was used. In all three studies, the coffee was brewed by a specialty coffee professional out of the sight of the participants. The mean temperature of the coffee served to the participants was 59.1°C (SD=4.2) in Experiment 1 and 60.2 °C (SD=2.1) in Experiment 2. The temperature of the coffee samples served in the preliminary study was not assessed.

2.2.2. Tactile stimuli

Swatches of sandpaper (40×50 mm), rough on both sides, were used in the preliminary study. Sandpaper was fine coarse grade (P150) with the intention of mimicking a rough, not polished, ceramic cup. The sandpaper was dark grey in colour (see Figure 1A).

Smooth and rough coffee cups were used as stimuli in Experiments 1 and 2. The smooth cup was the 'tulip' shape from the Oslo series (Figgjo, Oslo, Norway) developed by Tim Wendelboe (Oslo, Norway). The cup is made of white porcelain and it is smooth on both outside and inside walls. The rough cup was the 'nutty' shape from the Brewers series (Loveramics, Hong Kong, China). The cup is made of white ceramic with a rough finish on both the outer and inner walls. Both cups were similar in their bulbous shape, weight [smooth (173.0g±1.9); rough (142.1g±3.0)], and height (smooth: 6.5cm; rough: 6.0cm) (see Figure 1B).

2.3. Design and procedure

Prior to the two main experiments, a preliminary study – or pre-test – was conducted during the 5th Roasters Village, a specialty coffee event that took place in Izhevsk, Russia, in order to explore whether touching a rough material would affect people's experience of the multisensory flavour perception in specialty coffee. All of the attendees at the event were encouraged to take part in the pre-test. All were coffee experts (12 roasters, 7 baristas, 3 graders, and 9 coffee shop owners, with 6 Q-graders[5] amongst them). The pre-test took place in a specialty coffee shop located in Izhevsk (Tasty Coffee), and was designed with the 'presence' vs. 'absence' of the rough tactile material (sandpaper) as the within-participants factor. All of the participants were assessed in a single round. Each participant was seated at a table with two paper questionnaires, for the 'presence' or 'absence' of the sandpaper, and received a three-minute briefing on their evaluation task. Each participant then received one cup containing approximately 100 mL of filter coffee. The same white porcelain cup was used for all participants. The participants were instructed to evaluate the coffee sample first without touching the sandpaper. They started by rating the basic tastes requested (i.e., sweetness and bitterness). Next, they moved on to rating the coffee's body intensity. After they had swallowed, they were asked to rate the intensity of the coffee's aftertaste. Ratings were performed using a 10-cm visual analog scale anchored with 0 ('not at all') and 10 ('very'). The participants were also instructed to write down descriptors of body and aftertaste that they might have noticed in the sample. Once they had completed the first questionnaire, they were instructed to start the evaluation over but this time the coffee sample was to be tasted while rubbing the sandpaper with their non-dominant hand (given that they were holding the cup in their dominant hand). In addition to the intensity ratings, the participants were asked to provide a qualitative description of the coffee attributes 'body' and 'aftertaste' in both conditions (i.e., with and without sandpaper). They were instructed to focus on sensory descriptors only and to avoid hedonic terms. They were further instructed that tactile descriptors should be used for 'body' whereas both tactile and gustatory (basic tastes) descriptors should be used for 'aftertaste'. It is important to notice that the two conditions were not counterbalanced amongst participants.

Both Experiments 1 and 2 took place in Brazil and followed a between-participants experimental design. The participants were divided into two testing groups according to the texture of the cup from which the coffee was sampled (i.e., rough or smooth). Exactly the same data collection procedure was used in both experiments, the differences being the (i)

[5] Q-graders are the cupping certified judges according to the international Q Coffee System methodology (Lingle & Menon, 2017).

location in which the tests took place and (ii) the level of expertise of the participants (described below).

Experiment 1 was conducted during the 6th International Coffee Week, the largest specialty coffee event held in Brazil, at the BUNN booth, and only Q-graders were tested (please see footnote 4). The experiment was announced at the event encouraging the Q-graders to approach the testing booth for further information. Prior to the start of the experiment, the participants were informed that they would taste and evaluate one sample of specialty coffee, and were required to complete a short questionnaire assessing their age, gender, nationality, and Q-grader certification. Participants from 11 countries were assessed[6], and they were tested in two groups of three. Two round tables were placed at the centre of the booth, and each group of three participants was then seated around one of these two tables. Each group (i.e., each table) received the coffee sample in the same cup texture.

Experiment 2 took place in a testing room at Sofa Cafe, a coffee shop and school in Sao Paulo, and only amateur consumers were tested. The majority of the participants were recruited primarily through social media websites with online adverts making clear the experimental procedure as well as the inclusion criteria, that is, regular consumers who had been drinking specialty coffee for at least a year with no sugar added. The participants filled in a short questionnaire on their familiarity on specialty coffee and consumption frequency (low: 1-3 times/month; medium: 1-3 times/week; high: daily). They were also informed that they would taste and evaluate one sample of specialty coffee. The participants were led, in groups of six, to the testing room and were then seated one at each table, with at least one-metre spacing between adjacent tasters.

For both Experiments 1 and 2, a sheet containing the rating scales, a pen, and a glass of water were placed in front of each participant's place prior to their arrival at the testing room/booth. At the start of each testing session, the group of participants received a three-minute briefing to ensure that they were all given the same instructions prior to the study. Each participant then received one cup containing approximately 50 mL of brewed coffee. The participants were instructed to evaluate the aroma before tasting the coffee using the aroma rating scale. Next, they moved on to tasting and rating the coffee's basic tastes (i.e., sweetness and acidity

[6] Regarding the nationality of the participants: 29 from Brazil; 9 from Colombia, 4 from France, 7 from Germany, 5 from Italy, 4 from Japan, 2 from Mexico, 5 from Spain, 4 from Switzerland, 8 from the US, and 4 from the UK.

– with the order counterbalanced across participants), followed by its body. After they had swallowed the coffee, they rated its aftertaste. Ratings were performed using a 10-cm visual analog scale anchored at 0 (‘not at all’) and 10 (‘very’) for aroma, sweetness, and acidity. For body and aftertaste, a continuous semantic differential scale was used anchored at the polar terms ‘totally smooth’ (0) and ‘totally dry’ (10). Each testing session lasted for around 7-10 min.

One supervisor was present during the testing sessions in order to provide any guidance as necessary. Upon finishing the study, the participants were thanked for taking part and instructed to leave the room. In Experiment 2, they received a small sample of specialty coffee in return for taking part in the study.

2.4. Data analyses

Data from the pre-test were analysed using repeated-measures multivariate analysis of variance (MANOVA), with ‘sandpaper’ (present vs. absent) as the within-participants factor. The model included the intensity of aroma, bitterness, sweetness, body, and aftertaste as dependent measures. A between-participants MANOVA was conducted on the data from Experiments 1 and 2. The texture of the cup (smooth vs. rough) was the between-participant factor, and aroma, sweetness, acidity, body, and aftertaste were the dependent variables. All of the post-hoc pairwise comparisons were Bonferroni corrected.

3. Results

3.1. Preliminary study

For the pre-test, the repeated-measures MANOVA revealed a significant main effect of the sandpaper [$F(1,30)=4.06$, $p=0.043$; Wilks’ lambda=0.71]. Subsequent univariate tests revealed that sandpaper had a significant effect on ratings of aftertaste intensity [$F(1,30)=6.26$, $p=0.018$], but not on any of the other attributes that were assessed (i.e., bitterness, sweetness, and body). A post-hoc comparison revealed that the coffee was perceived as having a more intense aftertaste when the participants simultaneously touched the sandpaper swatch whilst tasting the coffee (5.15 ± 0.20) as compared to when they sampled the coffee without rubbing the sandpaper (4.41 ± 0.20) ($p<0.0001$) (see Figure 2).

The frequency of sensory descriptors that were used to describe the attributes 'body' and 'aftertaste' of the coffee sample in the two conditions (i.e., sandpaper present vs. absent) is summarized in Table 1. It is interesting to note that 'rough' and 'dry' were the most frequent descriptors used to describe, respectively, body, and aftertaste when the participants tasted the coffee whilst touching the swatch of sandpaper. In addition, descriptors of basic tastes were also used by the coffee experts for the aftertaste description in both conditions. The word 'sweet' was frequently used in the 'sandpaper absent' condition whereas the terms 'acid' and 'tart' were frequently used in the 'sandpaper present' condition. In addition, the participants were also allowed to use more complex flavour terms in order to describe the aftertaste in both conditions. These terms were then divided into 'positive' and 'negative' descriptors as, for instance, 'dusty', 'heavy', and 'not pleasant' for negative descriptors, and 'nutty', 'fruity', and 'caramel' for positive descriptors. The frequency with which positive and negative aftertaste descriptors appeared in each of the two conditions amongst all participants is also listed in Table 1.

3.2. Experiments 1 and 2

Data from Experiment 1 (Q graders) and Experiment 2 (amateur consumers) were analysed separately. The between-groups, one-way MANOVA revealed a significant effect of the texture of the cup on participants' ratings of the expected taste attributes of the coffee in Experiment 1 [$F(1,80) = 31.31$, $p < 0.0001$, Wilks' lambda = 0.32, $\eta^2_p = 0.68$] and Experiment 2 [$F(1,116) = 3.10$, $p = 0.012$, Wilks' lambda = 0.88, $\eta^2_p = 0.13$].

Follow-up univariate tests revealed that cup texture had a significant effect on ratings of aftertaste in both experiments [Experiment 1: $F(1,80) = 133.74$, $p < 0.0001$, $\eta^2_p = 0.63$; Experiment 2: $F(1,116) = 7.27$, $p < 0.01$, $\eta^2_p = 0.07$]. The texture of the cup also had a significant effect on acidity ratings in Experiment 1 [$F(1,80) = 7.21$, $p < 0.01$, $\eta^2_p = 0.09$], and on sweetness ratings in Experiment 2 [$F(1,116) = 7.03$, $p < 0.01$, $\eta^2_p = 0.07$]. There were no significant effects of cup texture on the dependent variables 'aroma' and 'body' in either experiment (see Figure 3).

Post-hoc comparisons revealed that the aftertaste of the coffee was perceived as drier when sampled from the rough cup than from the smooth cup in Experiment 1 (rough cup: 6.67 ± 0.23, smooth cup: 2.88 ± 0.21) and Experiment 2 (rough cup: 5.33 ± 0.25, smooth cup: 4.33 ± 0.27). In Experiment 1, the coffee was judged as tasting more acidic when tasted from the rough cup (6.02 ± 0.24) than from the smooth cup (5.16 ± 0.20). Finally, the coffee was also rated as tasting sweeter from the smooth cup (6.10 ± 0.21) than from the rough cup (5.18 ± 0.28) in Experiment 2. The demographics and results of Experiments 1 and 2 are summarized in Table 2 (see also Figure 3).

4. Discussion

In the present study, we tested whether coffee cups with two different surface textures (i.e., smooth and rough) would influence ratings of the aroma, taste, and tactile attributes given by specialty coffee professionals (Q-graders) and amateur consumers. The findings clearly show that the surface texture of the coffee cup affects people's perception of the flavour of specialty coffee, with strong main effects on the mouthfeel aspects of aftertaste evaluation.

The two main experiments were preceded by a pre-test in which sandpaper swatches were used to present the rough haptic/tactile sensation. The results of the pre-test show a significant effect of touching the rough surface whilst drinking coffee on the perceived intensity of the aftertaste. However, the rough texture did not influence the perception of bitterness, sweetness, or mouthfeel. In addition to intensity ratings, the participants were also asked to provide qualitative descriptors for the attributes 'body' and 'aftertaste'. The coffee body was described as 'rough' and 'dense', and the aftertaste as 'dry', 'acid/tart', and also 'lasting' when the participants were touching the sandpaper swatch. Instead, the terms 'smooth' and 'round', and 'sweet' and 'short' were frequently used to describe the body and aftertaste, respectively, when the participants were not touching the sandpaper. Despite the lack of a sensorimotor control condition for the act of rubbing in the pre-test, these preliminary results seem to suggest an effect of the rough surface on body and aftertaste perception. It is also important to mention that the conditions were not counterbalanced, thus the effect of task order cannot be ruled out. In the following experiments, the dependent variable 'bitterness' was replaced with 'acidity' due to its frequent use as a descriptor.

The results of Experiments 1 and 2 demonstrate that haptic sensations from touching coffee cups with different surface textures influence the coffee drinking experience. In line with previous reports showing that an off-dry Chardonnay wine and a red dessert wine were rated as tasting sweeter when participants were instructed to touch velvet rather than sandpaper (Wang & Spence, 2018), in Experiment 2 the coffee was perceived as sweeter when tasted from a smooth, as opposed to a rough, surface cup. In Experiment 1, the coffee was rated as more acidic from the rough cup than when tasted from the smooth cup instead. Interestingly, Van Rompay et al. (2017) reported that the angular textured cup enhanced the bitterness ratings of the coffee used in their study. The specialty coffee grading system negatively scores dominant bitterness and positively scores the presence of sweetness and 'vibrant acidity' (Traore, Wilson, & Fields, 2018). Thus, specialty coffees essentially lack dominant bitterness but will express varying levels of acidity, which may also be enhanced by rough textures. For instance, Slocombe et al. (2016) demonstrated that lemon curds were rated as significantly more acidic when given a rough, instead of smooth, coating (despite finding no effect of the texture of the serving plate on the same food) suggesting that perception of acidity might be enhanced by rough textures. Taken together, these results suggest that the perception of basic tastes (i.e., sweetness and acidity) in specialty coffee may be influenced by the haptic cues related to the coffee cup.

Regarding the effect of the surface texture of the cup on the oral-tactile attributes, no significant effect on the perception of body was observed, but there was a strong effect on judgments of dryness vs. smoothness of the coffee's aftertaste. In fact, as mentioned earlier, a recent study (Wang & Spence, 2018) reported that touching sandpaper or velvet swatches whilst evaluating a red dessert wine did not influence the perception of tannins in the mouth, i.e., the judgment of astringency in the mouthfeel, although the tactile sensation of the aftertaste was not assessed. Another recent study could be useful in understanding the impact of the product-extrinsic touch on mouthfeel dimension (Biggs et al., 2016). Their first experiment showed that the perception of 'gingeriness' of ginger biscuits was enhanced by the rough (as compared to smooth) feeling of the plate in the participants' hands whilst consuming the biscuits. These higher ratings could reflect an increase of 'gingeriness' in perception not only in the flavour itself (i.e., when the participants were eating/masticating the biscuit), but also in the aftertaste (i.e., a few seconds after swallowing), but these two temporal points were not assessed by the study.

The influence of haptic cues on perception of aroma has been reported before. For instance, wines were rated as having a fruiter aroma when tasted when the participants touched a swatch of velvet as compared to when touching sandpaper (Wang & Spence, 2018), and the fragrance of a body soap as being more intense when presented in heavier (rather than lighter) packaging (Gatti, Spence, & Bordegoni, 2014; cf. Kampfer, Leischnig, Ivens, & Spence, 2017). In the present study we failed to demonstrate an effect of texture on aroma, suggesting limitations on the conditions (e.g., food attributes, experimental setup) under which haptic cues influence perception. One possible explanation for this null result is that aroma was assessed as a single attribute instead of specific aroma qualities known to be present in the beverage (e.g., fruity, spicy).

It is also important to note that the observed effects of the cup surface texture on taste and mouthfeel attributes of coffee could be due to haptic information presented to the hand and/or felt on the lips, since the texture covered the whole outside wall of the cup. It has been shown that haptic information from the hand (e.g., touching, bending) is integrated with information from the mouth (e.g., bit-into with the teeth), altering perceived texture of the food product (Barnett-Cowan, 2010). It would be interesting to further investigate the contribution of haptic and lips extrinsic cues using cups with congruent and incongruent hands/lips textures.

One way to understand how the haptic properties of the servingware may impact dimensions and features across distinct oral sensory modalities, such as gustation and oral-somatosensation, is in terms of the sensation transference effect (Cheskin, 1972; see Skaczkowski et al., 2016, for a recent review). Sensation transference is generally thought to occur when product-extrinsic information triggers expectations of certain flavour characteristics to the product itself. These expectations then act as a framework for the interpretation of the actual sensory input. In this way, some of the sensations regarding the attributes of the receptacle or packaging may be transferred to the product contained within.

Sensation transference depends largely on the type of expectations certain product-extrinsic information elicits, and whether the expectations can be more-or-less fulfilled, or matched, by the flavour properties of the actual product. For instance, it has been reported that the smooth feeling of packaging or servingware in the consumer's hands can enhance the perception of sweetness of what is consumed (see Spence, 2019a, for a review). But this effect will be observed if and only if the product has some level of sweetness in the first place. Thus, a haptic cue would work to magnify (or draw attention) to a certain taste/flavour attribute that is already present. This might be a limitation on the conditions under which haptic cues influence flavour perception, and might shed light on some of the null results reported in the literature (for instance, the lack of effect of smooth vs. rough container on yoghurt mouthfeel ratings; Piqueras-Fiszman & Spence, 2012).

In the same way high levels of bitterness represent a negative attribute in specialty coffee, dominant astringency can also be classified as a primary defect of the beverage (Lingle & Menon, 2017). However, according to the rationale presented above, astringency/dryness must already have been present in the stimulus (i.e., coffee) for its perception to be enhanced in the aftertaste by the rough cup (in contrast to the smooth cup). Actually, the perception of astringency/dryness in coffee is not necessarily tied to the level of chlorogenic acids as is commonly assumed (Buffo & Cardelli-Freire, 2004). Along with acidity, some organic acids can also induce sensations of astringency in an inverse, pH-dependent relationship between acidity and perceived astringency (Bajec & Pickering, 2008). One of the organic acids capable of inducing the sensation of dryness is citric acid, which is naturally and widely present in brewed coffee (Sunarharum, Williams, & Smyth, 2014). Therefore, a specialty coffee with low levels of chlorogenic acids but with a low pH citric acid (hence leading to a non-dominant astringency) may be perceived as fairly dry in the aftertaste when consumed from a cup having a rough finish.

Extrinsic cues, in turn, can act as explicit or implicit primes depending on the context, and this can affect the mechanism through which sensation transference may occur (Dijksterhuis, 2016). In fact, both the prime and the subsequent measurement can be influenced by several external factors, and as a result, primes can produce very different responses depending on the testing situation (Loersch & Payne, 2011). For instance, different task instructions given to participants in order to make them know (or not know) they are potentially under the influence of a prime could dissociate implicit from explicit feature processing (Piqueras-Fiszman, Velasco & Spence, 2012). Explicit task instructions could raise awareness of the prime, and the conscious information processing could influence the subsequent task part where an effect of priming can occur. On the other hand, implicit instructions could distract the participant from finding out what the prime is, and what the effect could be, and feature processing would take place outside the awareness of the participant. This could as well alter participants' responses to the subsequent stimuli (for a detailed "taxonomy of primes", see Dijksterhuis, 2016). Differently from the pre-test in which participants were tested in both conditions (comparative setup) and, thus, were explicitly asked to rub the sandpaper, both Experiments 1 and 2 followed a between-participant design. Thus, each participant evaluated the coffee from one of the two experimental cups, either rough or smooth, without being aware of the other option, or without having their attention deliberately drawn to the texture of the cup itself. Thus, our results suggest some level of automaticity on the mechanisms underlying this type of crossmodal correspondence (i.e., haptic texture and oral-somatosensory sensation), at least in the sense of it not being dependent upon the participants' awareness of the stimuli sensory properties (see Spence & Deroy, 2013 for a review). Notice that this single-shot procedure argues against this particular crossmodal correspondence being relative in nature (see Spence, 2019b, on the relative nature of e.g., pitch-based correspondences).

It is important to mention that, at present, the concept of sensation transference is more descriptive rather than explanatory. It is certainly necessary that future research could look for a more mechanistic understanding of the conditions under which it occurs and perhaps also its neural correlates.

Finally, it is worth noting that coffees of different varieties and *terroirs* were used in Experiments 1 and 2 (Yellow Catuai from Matas de Minas and Yellow Bourbon from Sul de Minas, respectively) and this is a main limitation of the present study. These coffees did have distinct flavour profiles as described in the Methods section. Hence, the factor 'experience' is therefore confounded with 'coffee type' preventing further comparison of data from both experiments to assess the possible main effects of cup texture and experience level, as well as interaction between these factors. In addition, the significant effects reported in Experiments 1 and 2 cannot be attributed to the experience level alone, since possible coffee type effects (as a confounder) cannot be ruled out. In fact, it is interesting to mention that a large difference in effect-size was found between Experiments 1 and 2 for the aftertaste ratings. However, as stated above, given that coffee type differed between experiments, we cannot explain this difference based solely on level of expertise. Further investigation is needed in order to understand whether coffee professionals who have been trained to identify and verbally report complex sensations such as dryness/roughness in the palate would be more susceptible to external haptic influences. It is plausible that coffee experts, who are more attuned to subtle differences in roughness of mouthfeel, might experience greater differences due extrinsic tactile cues (Wang & Spence, 2018; Hughson & Boakes, 2001). Importantly, the limitation caused by the potential confounding effects does not detract from our interpretation and inferences from the current data.

5. Conclusions

In summary, the results of the present study demonstrate for the first time that 'sensation transference' from the haptic feel of cup texture can significantly affect the quality of specialty coffee aftertaste in both experts (Q-graders) and amateur consumers. The present research therefore supports the view that the drinking vessel is a necessary component of the multisensory coffee drinking experience. Thus, the specialty coffee companies might want to focus not only on the sensory characteristics of the coffee beverage itself, but on the service alike. Indeed, the results reported here have critical implications for those designing servingware for specialty coffee.

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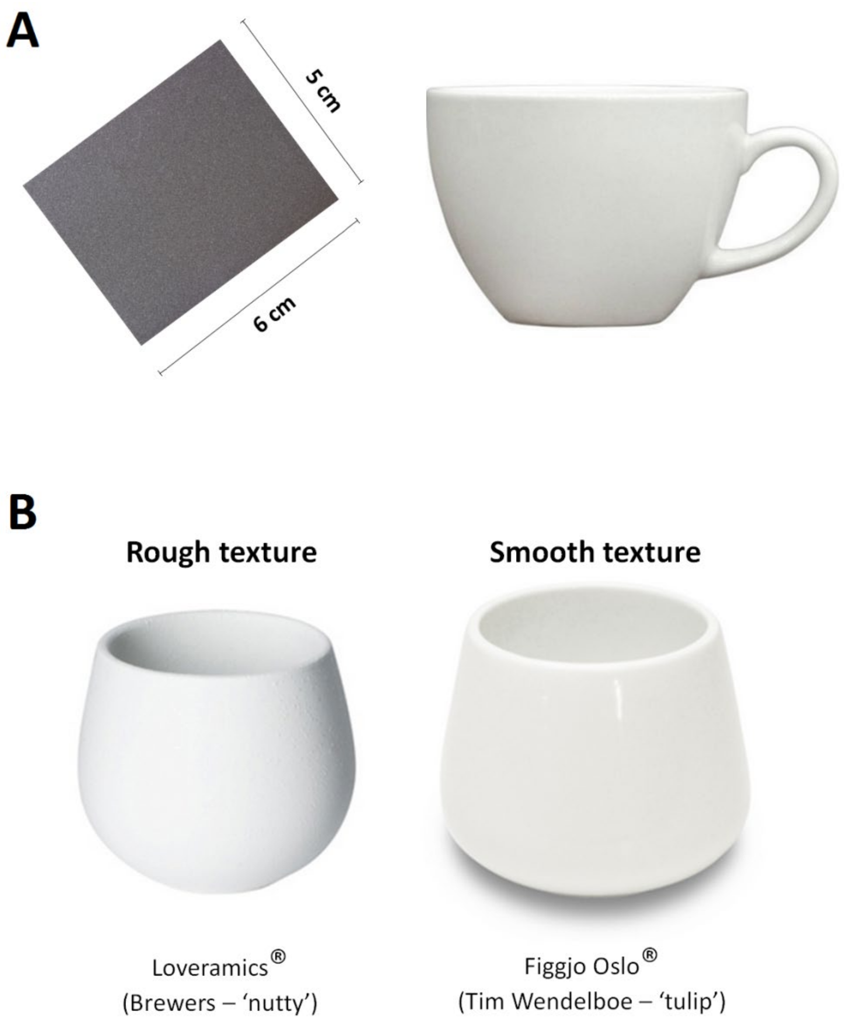

Figure 1: (A) Texture stimulus used in Experiment 1. The participants rated the taste and oral-somatosensory attributes of the same coffee sample served in a white porcelain cup whilst either touching a sandpaper swatch or not (Conditions 1 and 2, respectively); **(B)** The cups used in Experiments 2 and 3. The participants were served the same coffee in either a rough ceramic cup or a smooth porcelain cup and rated the coffee's aroma, taste, and oral-somatosensory attributes.

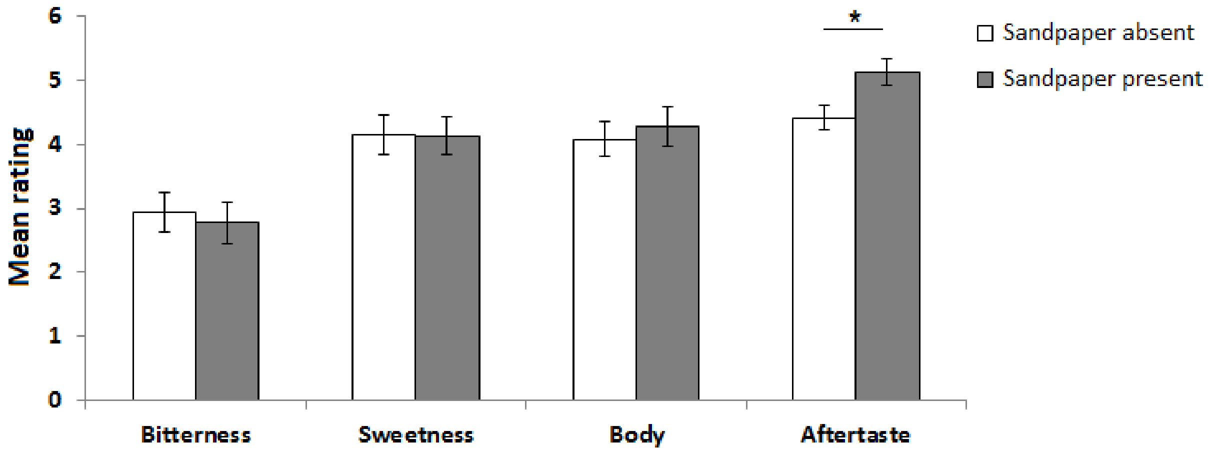

Figure 2: Pre-test. Mean ratings (± SE) of bitterness, sweetness, body, and aftertaste for the conditions ‘sandpaper absent’ (white bars) and ‘sandpaper present’ (grey bars). All attributes were rated in terms of ‘intensity’ using 10-cm visual analog scales anchored at 0 (‘not at all’) and 10 (‘very’). The *asterisk* (*) indicates statistical significance of ratings between conditions at $p < 0.05$ (Bonferroni corrected).

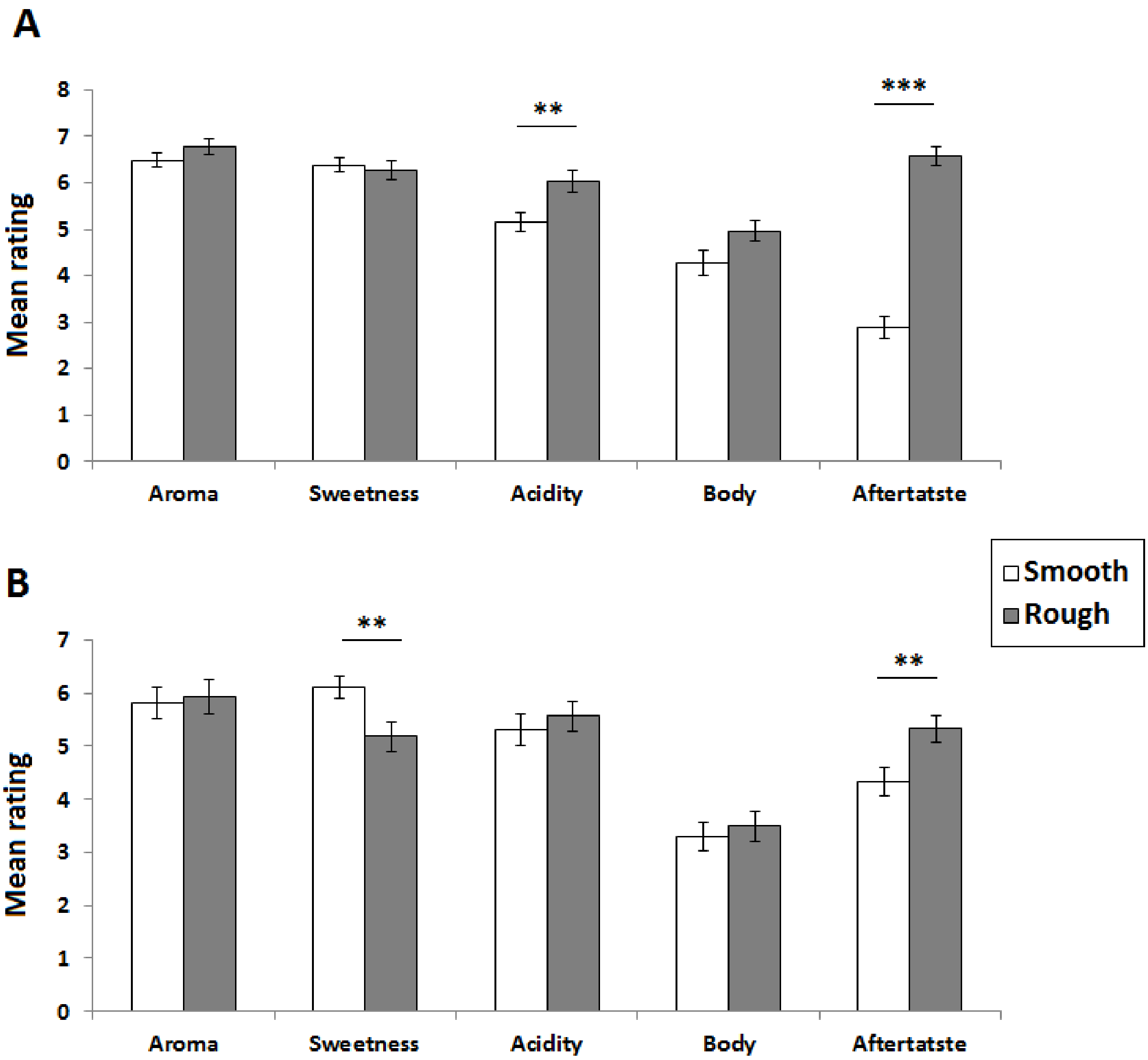

Figure 3: Mean ratings (± SE) of aroma, sweetness, acidity, body, and aftertaste for the smooth (white bars) and rough (grey bars) cups in (**A**) Experiment 1 (Q-graders) and (**B**) Experiment 2 (amateur consumers). The attributes aroma, sweetness, and acidity were rated in terms of 'intensity' (0 - 'not at all'; 10 - 'very') whereas the attributes body and aftertaste were judged on a continuous 'smooth-to-dry' bipolar scale (see Methods). The *asterisks* indicates statistical significance of ratings between smooth and rough cups at $p < 0.01$ (**) or $p < 0.0001$ (***) (Bonferroni corrected).

Table 1: Pre-test. Frequency of terms used to qualitatively describe the attributes 'body' and 'aftertaste' in both testing conditions (i.e., with and without sandpaper).

Descriptor	Tactile stimulus	
	Without sandpaper	With sandpaper
	Body	
Rough	4	8
Smooth	8	3
Dense	0	7
Light	6	2
Dry	0	5
Syrupy	2	0
Juicy	4	0
Round	7	4
Creamy	4	2
Velvety	2	0
Silky	3	0
	Aftertaste	
Short	11	4
Lasting	4	11
Dry	2	14
Acid/tart	1	10
Sweet	12	2
Bitter	0	6
Positive flavour attributes[7]	37	19

[7] Positive flavour attributes refer to positive terms used by the tasters to describe flavour residue remaining in the mouth after swallowing the coffee. Examples of positive flavour attributes used by the participants include 'chocolate', 'toffee', and 'grapefruit'. These contrast with negative attributes/terms such as 'burnt' and 'dusty'.

Table 2: Participant demographics and ratings of flavour attributes (mean ± SE) in Experiments 1 and 2.

	N	Gender	Age (yrs)	Level of expertise	Aroma		Sweetness		Acidity		Body		Aftertaste	
					S	R	S	R	S	R	S	R	S	R
Exp 1	81	38 F	35.5±5.5	Q-graders	6.5±0.2	6.8±0.2	6.4±0.2	6.3±0.2	5.2±0.2**	6.0±0.2**	4.3±0.3	5.0±0.2	2.9±0.2***	6.6±0.2***
Exp 2	117	59 F	33.4±8.5	Amateurs 5 L; 34 M; 78 H	5.8±0.3	5.9±0.3	6.1±0.2**	5.2±0.3**	5.3±0.3	5.6±0.3	3.3±0.3	3.5±0.3	4.3±0.3**	5.3±0.3**

N = number of participants; F = female; S = smooth; R = rough.

L = low (1-3 times/month), M = medium (1-3 times/week), and H = high (daily) stand for the three levels of consumption of specialty coffee amongst the amateur consumers tested.

**$p < 0.01$; ***$p < 0.0001$ (Bonferroni corrected)