8-2018

Influences of Intrinsic and Extrinsic Hand-feel Touch Cues on Sensory Perception and Emotional Responses toward Beverage Products

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Influences of Intrinsic and Extrinsic Hand-feel Touch Cues on Sensory Perception and Emotional Responses toward Beverage Products

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Food Science

by

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University of Wisconsin-Madison
Bachelor of Science in Food Science, 2014

August 2018
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This thesis is approved for recommendation to the Graduate Council.

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ABSTRACT

Consumer perception of and preference toward products are influenced by intrinsic product-specific (e.g., product temperature) and extrinsic non-product-specific (e.g., packaging or container) characteristics. Besides communicating information between products and consumers to create expectations toward the content at the point of sale, packaging also influences sensory perception of the content during consumption. Previous cross-modal studies on packaging effects on the content had largely overlooked hand-feel touch cues. Touch closely relates to consumers' emotional responses to and their quality evaluation of products. One way to manipulate hand-feel touch cues in a beverage consumption setting is to vary materials of cup sleeve, which are served concurrently with brewed coffee (BC) and green tea (GT). This thesis aimed to determine **1)** influences of intrinsic cues (product temperature) on sensory perception of and emotional responses to BC and GT; **2)** cross-modal association (CMA) of extrinsic hand-feel touch cues (12 sleeve materials) with evoked emotions, basic tastes, and coffee-related flavors; and **3)** cross-modal influences of extrinsic hand-feel touch cues (4 sleeve materials) on emotional responses, sensory perception, arousal, and valence of BC. Results showed both intrinsic and extrinsic cues influenced emotional responses to and sensory perception of BC and GT. Beverages at higher temperature were characterized by positive emotions, while those at room and cold temperatures were characterized by low arousal-negative emotions and high arousal-negative emotions, respectively. CMA between hand-feel touch and taste cues were confirmed to exist: bitter taste and black coffee flavor with cardboard sleeves; sweet taste and creamy flavor with towel; sour taste with stainless steel; and salty taste with linen. Correlations between certain textural parameters and sensory CMA were also observed: thicker and rougher materials positively correlated with positive emotions and sweet taste, while thinner and smoother materials positively correlated with negative and high-arousal emotions and sour taste. Additionally, coffee presented with samples (towel, linen, or stainless steel) were perceived differently, in terms of both emotions and sensory attributes, compared to cardboard (control). As highlighted here, touch cues are important in product evaluation. Professionals in food and beverage industries should consider incorporating more hand-feel textural features on product packaging or container designs.

Keywords: touch, product temperature, emotional response, sensory attribute, coffee, green tea, cross modal

ACKNOWLEDGEMENTS

I would like to express my most sincere gratitude to my advisor, **Dr. Han-Seok Seo (Associate Professor, Department of Food Science)** for the continuous support and guidance throughout my M.S. graduate career, as well as constant encouragement and advice, whether academic or personal. I would also like to thank and express my appreciation for my committee members, **Dr. Jean-François Meullenet (Director, Arkansas Agricultural Experimental Station)** and **Dr. James Lampinen (Distinguished Professor, Department of Psychological Sciences)** for their invaluable time and advice. Additionally, without the help of my team at the Sensory Service Center, the completion of this thesis would not have been possible. I would like to extend my thanks to **Mrs. Tonya Tokar (Former Laboratory Manager), Mrs. Tina McMaster (Laboratory Technician)**, **Ms. Peggy Pang (Laboratory Technician)**, **Mr. Matthew Chapko (M.S. Graduate)**, **Ms. Asmita Singh (M.S. Student)**, **Ms. Shilpa Samant (Ph.D. Candidate)**, and **Ms. Sara Jarma Arroyo (M.S. Graduate)** for their humor, suggestions, advice, time, encouragement, and most importantly, friendship. Finally, to my family (**Kiki Pramudya**, **Nani Halim**, **Adyuta Pramudya**, and **Priscilia Tunas**) and my friends, thank you for being there through all the highs and lows. I am extremely grateful for you all for helping me accomplish my dreams and helping me grow to be a better person, professionally and personally. Thank you.

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CHAPTER 1. General Introduction

Products are composed of both intrinsic and extrinsic cues that merge together to form impressions perceived by consumers (Fetai et al., 2017). Intrinsic cues are product-specific attributes, e.g., sensory properties and product temperature, while extrinsic cues are defined as external attributes that can be manipulated without changing the product itself, e.g., price, brand, packaging, container, and other environmental factors (Olson & Jacoby, 1972; Aqueveque, 2006).

Research on the effects of intrinsic cues on consumer acceptance and preference, especially in the food and beverage fields, had been extensively done. Among the few topics yet to be studied to a greater depth is the effects of product temperature. Although several research had been conducted in this area, few had focused on the effects of product temperatures on the emotional responses of food and beverage products. Rather, existing literature had emphasized how product temperature could influence sensory perception instead. Food-evoked emotions had been shown notably influence food acceptance and choice (King & Meiselman, 2010; Dalenberg et al., 2014; Gutjar et al., 2015). Therefore, it would be of great interest to determine how product temperature, a form of intrinsic product characteristic, could influence both sensory perception and emotional responses in a food or beverage product.

The information derived from external cues had been found to create expectations towards the products even before consumers purchase and use them. In particular, packaging appeared to be one of the most important aspects of consumer purchase decision at the point of sale, as consumers may classify packaging and content together as part of the overall product (Prendergast & Pitt, 1996; Silayoi & Speece, 2004). Unsurprisingly, findings of previous literature had revealed that packaging could influence the perception and experience of the content during point of sale, product usage, and consumption (Becker et al., 2011). Lefebvre et al. (2010) also found that consumers create expectations toward the content using sensory information extracted from packaging, including from handling the product during consumption, such as touching the packaging while opening or holding the packaging during consumption of the content. As observed in this instance, touch is an integral part of food and beverage consumption experience.

As a field of study, hand-feel touch is the least investigated sensory modality in the context of food and beverages. Indeed, due to the comparatively smaller portion of the world population that utilize their hands as a means of consumption, the influences of touch stimuli have been largely overlooked. However, as demonstrated in the above example, hand-feel touch cues devise a form of interaction between packaging and contect for consumers. Existing studies showed that there are several advantages for retailers to allow for hand-feel touch evaluation of products by consumers. Namely, for products possessing attributes best explored using hand-feel touch, hand-feel touch inputs positively affected product evaluation, in addition to further enhancing product quality when the product was deemed of high quality (Grohmann et al., 2007). Moreover, McCabe and Nowlis (2003) discovered that consumers preferred products from retailers who allowed them to appraise the poducts using their hands. Research on sensory dominance demonstrated that for majority of products, touch, along with vision, dominates throughout the entire cycle of product usage, from point of sale to usage (Fenko et al., 2010). As Hultén et al. (2009) mentioned: *"Seeing is reinforced by touch, in that touch helps us get a fuller understanding of what we see"*. In this manner, it is clear that touch could potentially aid companies to improve consumer preference and purchase decision towards their products. As such, the influences of hand-feel touch cues must be studied to a greater depth.

In addition, touch has historically provided a means of communication of either positive or negative emotional responses (Knapp & Hall, 1997; Hertenstein & Keltner, 2006). Therefore, it would be highly likely that touch stimuli would elicit emotional responses. Desmet (2010) postulated that a product could evoke emotional responses in an individual depending on its perceived product quality, associated connotations and meanings, and its performance or usefulness in the appropriate context. In all, touching a product could enhance and complete the human-product interaction with touch providing a sense of pleasure from a tangible object

(Ortony et al., 1988). Therefore, due to this close relationship between touch and emotions and previous literature showing the role of emotions in food product acceptance, it would be imperative to investigate how hand-feel touch stimuli could affect elicted emotions from a product.

One way to incorporate hand-feel touch cues in food and beverage products is to manipulate the packaging or container design. As coffee is a popular beverage consumed across numerous cultures worldwide, a means to alter hand-feel touch cues in this product consumption experience is to vary the cup sleeve designs. Among the few studies focusing on manipulations of hand-feel touch stimuli (Deroy & Valentin, 2011; Piqueras-Fiszman et al., 2011; Biggs et al., 2016; Slocombe et al., 2016; Cavazzana et al., 2017; Kampfer et al., 2017; Mirabito et al., 2017; van Rompay et al., 2017), even fewer emphasized the effects of materials on other sensory modalities (Tu et al., 2015). As such, numerous possibilities for further research in this area to investigate other touch parameters are endless. In particular, the effects of materials evaluated using hand-feel touch would be of great interest due to the increasing demand for reusable materials in products used daily, such as cup sleeves.

The present thesis was designed to examine both intrinsic and extrinsic product cues. Intrinsic cues investigated in this project were in the form of product temperature (**Chapter 3**). More specifically, this thesis aimed to determine how product temperatures could influence sensory perception and emotional responses in coffee and green tea beverages. In **Chapter 4**, it was explored whether cross-modal association between hand-feel touch and gustatory cues existed by investigating how extrinsic product cues, in the form of varying cup sleeve materials evaluated using hand-feel touch, could be associated with emotional attributes, as well as both imagined and consumed basic tastes, and imagined coffee-related flavors. Instrumental measurements to quantitate the physical attributes of the different cup sleeve materials were included to hopefully provide some physiological explanation for the cross-modal association trends observed. Finally, in **Chapter 5**, it was examined the degree to which the hand-feel touch stimuli cross-modally influence the evoked emotional responses and sensory perception in brewed coffee.

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CHAPTER 2. Review of Literature

1. A sense of touch

1.1. Concept and definition

The concept of touch is well understood by all individuals, yet it is difficult to define. There is an abundance of contextual meanings of the word "touch" (Lindstrom, 2005). It can be used to express emotional connection to other individuals, i.e. "to lose touch" with a friend, or emotional reaction to actions of other individuals, i.e. feeling "touched" by caring gestures. Another common application of this word is to use it as a verb describing physical contact with an object, i.e. "touching a desk". This context is the one primarily referred to in the fields of sensory science, marketing, and neuroscience. In studies focusing on food texture perception, through whether hand-feel or mouthfeel, the term "surface texture" is generally the main attribute in concern. A clear definition of this term remains elusive, but the popular interpretation is that surface texture is a "multi-sensory parameter sensory factor composed of those surface-related features which can be perceived by visual, tactile hand-feel, and tactile mouthfeel senses" (Chen, 2007). Various research studies had been using the terms "haptic" and "tactile" interchangeably to refer to the perception by means of touch, but they cannot be defined as the same. Sherrington (1900) introduced the concepts of active and passive touch, which distinguishes the difference between haptic and tactile perception. The works of Gibson (1962) equated passive touch with the term "tactile perception" and active touch with "haptic perception" (Loomis & Lederman, 1986). Per Gunther and O'Modhrain (2003), the term "haptics" embodies everything referring to the sense of touch. The haptic system generally relates to a group of anatomical structures, more specifically somatosensory receptors, which allow individuals to perceive haptic stimuli and react accordingly. Haptic sensations can then be further categorized into two types of sensations: tactile sensation (or taction) and proprioception (or kinesthetic perception). Tactile sensation is typically related to the sensation of pressure, orientation, curvature awareness, texture, thermal properties, puncture, and vibration (Gunther & O'Modhrain, 2003). The primary means of which taction is perceived by the body is through stimulation to the skin (Rovan & Hayward, 2000), where cutaneous receptors (mechanoreceptors and thermoreceptors) are located (Greenspan & Bolanowski, 1996; Lederman & Klatzky, 2009). Proprioception provides the body information allow for awareness of body position and movement through stimulation to kinesthetic receptors (mechanoreceptors ingrained in muscles, joints, and tendons) (Kappers & Bergmann Tiest, 2015). Thus, the term “tactile” is a sub-category of the haptics system that is mediated only through cutaneous receptors, whilst the haptics system allows humans to perceive environmental stimuli through the sense of touch.

1.2. Anatomy and physiology

Touch is an important tool to alert humans of their well-being through the detection of temperature, vibrations, and weight information, as well as to inform them of the location of other objects (spatial awareness) (Lindstrom, 2005). The feeling of touch is sensed by the human body through stimulus detection on the skin, which triggers the nervous system to relay information to spinal cord, which eventually further delivers it to the thalamus and sensory cortex in the brain. As mentioned in the previous section, the haptic system comprises of two types of sensations: tactile (through “cutaneous” inputs) and proprioception (through “kinesthetic” inputs) (Lederman & Klatzky, 2009). Cutaneous receptors are located across the surface of the body, underneath both hairy and hairless parts, and consists of mechanoreceptors and thermoreceptors. Four main types of mechanoreceptors have been recognized: Merkel endings, Meissner corpuscles, Pacinian corpuscles, and Ruffini endings (Lederman & Klatzky, 2009; Kappers & Bergmann Tiest, 2015). The way that these receptors respond to stimuli is dependent on two factors: receptive field size (the range of region on skin in which the neurons can detect relevant signals) and relative adaptation rate (“one-time” response only when skin deformation is applied and another response when it is removed vs. continued response during sustained skin deformation) (Lederman & Klatzky, 2009). Rapidly adapting receptors transmit impulses to the brain at the moment that a stimulus is applied to the skin and again when the stimulus is removed, whilst slowly adapting receptors continue transmitting impulses as long as the stimulus is applied. Slow-adapting types include Merkel endings (SA I; small receptive field) and Ruffini endings (SA II; large receptive field), while fast-adapting types include Meissner corpuscles (FA I; small receptive field) and Pacinian corpuscles (FA II; large receptive field). Each of the four mechanoreceptors has its own features and functionalities (Lederman & Klatzky, 2009). Merkel endings capture information about sustained pressure (Johansson et al., 1982) and spatial deformation (Johnson & Lamb, 1981), and function to detect very-low-frequency vibration (Löfvenberg & Johansson, 1984), perceive coarse texture perception (Blake et al., 1997), detect pattern/form detection (Johnson & Phillips, 1981), and manipulate stable precision grasp (Westling & Johansson, 1987). Ruffini endings detect high-frequency vibration detection (Löfvenberg & Johansson, 1984), perceive fine texture (Bensmaïa & Hollins, 2005), and manipulate stable precision grasp. (Westling & Johansson, 1987). Fast-adapting mechanoreceptor Meissner corpuscles could detect low-frequency vibration (Löfvenberg & Johansson, 1984), as well as manipulate stable precision grasp (Westling & Johansson, 1987). Finally, Pacinian corpuscles obtain information about sustained downward pressure, lateral skin stretch (Knibestöl & Vallbo, 1970), and low dynamic sensitivity (Johansson et al., 1982), and therefore function to detect direction of object motion and force due to skin stretch (Olausson et al., 2000), manipulate stable precision grasp and manipulation (Westling & Johansson, 1987), determine finger position (Edin & Johansson, 1995), and detect spatial deformation (Johnson & Lamb, 1981). The other cutaneous receptors, thermoreceptors, contribute to the human perception of warmth and cold (Stevens, 1991).

Somatosensory receptors show different degrees of sensitivity depending on skin type and their location in the human body (Greenspan & Bolanowski, 1996; Guinard & Mazzucchelli, 1996), with fingertips showing the most sensitivity as measured by two-point discrimination, followed by the upper lip, cheeks, and nose (Weinstein, 1986). In general, the same types of mechanoreceptors in the glabrous skin in the human body (e.g. hand) can be found in the tongue (Capra, 1995), with the exception of Pacinian corpuscles (FA II) that are absent in the oral tissues (Trulsson & Johansson, 2002; Marlow et al., 2004). During mastication, food texture can be sensed by several receptors at different parts of the oral system (Guinard & Mazzucchelli, 1996; Fujiki et al., 2001). Even before the food enters the mouth, the lips can detect food temperature and its surface roughness (Chen, 2007). Mechanoreceptors SA I (Merkel endings), are located at hard and soft palate, tongue, and gums (superficial structures). These display selective sensitivity to pressure and are located in the superficial layer of the lingual mucosa. These afferents allow for the perception of oral static stimuli because of their slow-adapting properties, which cause them to be able to respond to sustained pressure caused by deformation of the skin by food materials. The second mechanoreceptors, SA II (Ruffini endings), are located in the periodontal membrane (root of teeth), deeper in the mucosa, and determine the amount of force the teeth applies for mechanical breakdown of food, as well as the thickness of food (Boyar & Kilcast, 1986). RA I afferents (Meissner corpuscles) show poor sensitivity to both spatial recognizion and static stimuli, but high sensitivity to dynamic impulses (Johnson, 2001; Kutter et al., 2011).

Haptic hand-feel perception involves stimulation of sensory receptors on the skin. The skin consists of layers of tissues, with epidermis being the first layer and dermis being the second. In the glabrous (hairless) skin like fingertips, the intersecting boundary between epidermis and dermis contains mechanoreceptors arranged in such a way that helps receptor activation (Greenspan & Bolanowski, 1996). The epidermis acts as a protective layer composed of tough dead cells for the layers underneath and contains no sensory receptors. Most of the sensory receptors are embedded in the dermis layer, which consists of connective tissues and elastic fibers surrounded in a semifluid, amorphous complex called ground substance. A popular model of the physicoproperties of the skin likens the skin to a waterbed (“waterbed” model), where the skin is imagined as “an elastic membrane enclosing an incompressible fluid” (Srinivasan, 1989; Greenspan & Bolanowski, 1996). This model has been shown to agree well with in vivo data than other skin physicoproperties models (Srinivasan & Dandekar, 1996).

Although it had been suggested in the past that proprioception also contribute to the sensations of food texture in the mouth, it is largely dependent on the type of food consumed. In semi-solid foods where teeth are not generally used in physical food breakdown, it had been determined that proprioception through kinesthetic inputs plays a minor role, whilst mechanoreceptors play a larger role (Kutter et al., 2011). Very few, if not none, have studied the impact of proprioception and tactile perception on solid foods, but it would be expected that proprioception has a greater role because solid foods require more physical effort and movement by facial muscles, tendons, and joints, activating the kinesthetic receptors (Guinard & Mazzucchelli, 1996). The role of proprioception, as expected, has been found to be more significant in hand-feel tactile sensing, as demonstrated by Gibson (1962), of whose study reported better perception of two-dimensional objects (cookie cutters) with “active touching” (subjects allowed to freely explore the shapes with their hands, thus activating kinesthetic receptors) than by “passive touching” (subjects had the objects statically placed on their hands).

1.3. Factors influencing touch perception

Numerous factors affect the touch perception of food and other materials, whether felt through mouthfeel or hand-skin (Engelen & Van der Bilt, 2008). Besides independently influencing texture perception, many of these factors interact with each other to contribute to a complex overall perception. In general, the factors can be categorized into four different groups: product, environmental, physiological, and psychological. The product category concerns variables directly related to the product/stimulus that induce perceivable texture sensations, e.g., ingredients, ingredient composition and microstructure, flavor, production processes, and temperature. Attributes related to the environmental setup in which product processing is done by the subjects, e.g., packaging, lighting, tableware, utensils, social setting, and product handling, are included in the environmental category. Physiological and psychological aspects that influence texture perception are dependent on individual subjects. Physiological factors include dentition, tongue movements, saliva, demographics, thermal perception, health, and perception of product-induced sensory cues. Psychological aspects are more related to culture, experience, expectations, emotions, and personality. Factors regarding other sensory cues will be discussed in later sections.

1.3.1. Product-related factors influencing touch perception

It has been widely accepted that the food material itself affects its texture perception. Published studies investigating the effects of food composition and microstructure have largely focused on texture perception perceived orally. Oral mechanoreceptors have high sensitivity for the detection of food particle size (Hinton et al., 1970). It has been found that particles of minute size 5-25μm, depending on the food product, can be discriminated against by the oral mucosa system. As such, ingredient composition and microstructures are factors critical to human texture perception of food. This influencing factor has been well documented in many literatures. In semi-solid foods, e.g. custard, it has been found that high fat-containing custards were perceived to be thicker, creamier, and had higher fatty mouth-feel than the zero-fat samples (de Wijk et al., 2003). Another study found that the perceived smoothness of dairy cream samples increased with increased average distance between fat droplets and decreased average size of fat droplets (Richardson & Booth, 1993). Manipulating levels of certain ingredients in hummus (chickpea spread) has also resulted in different levels of perceived texture attributes. Jiménez et al. (2016) revealed that chickpea gels with higher curry powder showed lower force to breakdown, whilst samples with higher inulin displayed higher hardness. Besides ingredient content and arrangement, texture perception is also contingent upon product temperature

(Engelen et al, 2003; Drake et al., 2005). According to a study by Engelen et al. (2003), along with fat content, product temperatures also resulted in different perceived textural attributes in custard and mayonnaise samples. High product temperature displayed lower thickness ratings in both products, whilst high fat products received higher creaminess and thickness ratings. Another well-studied product-related factor influencing touch perception of food is its processing conditions. The most common treatments subjected to food products, such as heating and freezing, are done to ensure safe consumption and prolong shelf-life. In a study examining the effects of thermal processing on the sensory properties of broccoli, a processing condition combining 8 minutes of hot air with temperature of 125°C and 90% steam saturation resulted in samples characterized with firm structure and better consistencies than other conditions (Borowski et al., 2015).

Much of the work investigating hand-feel perception has focused on fabric or paper, but there has been a surge of interest on eating with one's hands in recent times, particularly in the restaurant industry. Jo Bryant, an etiquette advisor at a longstanding British publisher of etiquette guide Debrett's, has suggested that "the influence of other cultures and new foods…means eating with our hands is a growing trend" and that "table manners are no longer about adhering to a rigid, and outdated, code of conduct" (Furness, 2012; Spence et al., 2013). The perception of touch sensed with hand-skin, like oral touch perception, is also influenced by the characteristics of product material itself. Studies on in-hand sensory evaluation are fewer compared to oral evaluation, but those that have been published have successfully shown that human subjects could detect textural differences between samples with varying compositions and ingredients, as well as samples manufactured with different processing procedures. In one such study, cheese analogues with lower moisture content displayed firmer, curdier, and less sticky ratings than those with higher moisture content (Pereira & Bennett, 2002). Another study aiming to identify consumer texture preferences for a range of commercially produced dulce de leche used non-oral "manual" evaluation procedure (Ares et al., 2006).

1.3.2. Environmental factors influencing touch perception

Besides the influences of the food product itself, food texture as sensed by touch receptors in the mouth and skin covering other body parts can also be perceived differently via interactions with non-edible items associated with consumption (e.g. during handling in prepartion for food consumption) (Piqueras-Fiszman & Spence, 2012). These interactions are included under the category of non-diagnostic haptic cues, which are not objectively and directly relevant to product judgment but significantly influences consumers' perception of the quality of the product. As an example, in a study in which participants are allowed (vs. not) feel for the flimsy plastic cup in which water is poured in, hypothetically the quality of the water should be judged independently regardless of the cup it is in. However, this does not appear to be the case (Krishna & Morrin, 2008). This suggests that changing the haptic qualities of a packaging (or other environmental factors, like tableware, utensils, lighting, etc.) may critically affect a consumer's perception of the product. An explanation for this crossmodality effect is a phenomenon called "sensation transference" (Cheskin, 1957) or "affective ventriloquism" (Spence & Gallace, 2011). This term refers to the ratings of one sensory modality (e.g. touch) creating bias on a person's estimate of product quality or acceptance of another sensory modality. Most of the published studies on the effects of packaging, tableware, utensils, and other environmental factors have been primarily emphasized on the perception of taste/flavor, quality, and consumer willingness to purchase, whilst very few are dedicated to texture perception. In addition, most studies on texture perception have focused on the influences of packaging, tableware, and utensils, and very little, if not none, on lighting and other environmental factors, such as background music.

Amongst the few studies focusing on oral texture perception of food, Piqueras-Fiszman and Spence (2012) have shown that non-diagnostic haptic cues indeed significantly affect participants' ratings of texture attributes in biscuits and yogurts. Participants held the containers (smooth vs. rough-textured pots) before tasting the samples. On average, biscuits presented in pots with rough outside texture displayed higher crunchy and hardness ratings, whilst yogurts presented in pots with smooth texture displayed higher smoothness ratings. Similarly, another study resulted in the perception of biscuits being crunchier and rougher when tasted from a plate with rougher surface vs. smoother (Biggs et al., 2016). In an older study, the crunchiness of potato chips were rated higher when packed in polyvinyl bags than wax-coated paper bags, despite easier opening of the latter type of bags (McDaniel & Baker, 1977). The follow-up blinded study to this research showed that there was no significant difference in potato chips from the two different types of bags, further confirming that packaging properties can alter texture perceptions of food.

Studies investigating effects of non-diagnostic haptic cues on oral texture perception are not common due to its rare applications in the food and restaurant industries, i.e. it is very unlikely consumers will not use their hands to move food from a container to their mouth or be spoon-fed. As of now, there has been no scientific studies about this, but in the restaurant industry where there is a constant need for elements of excitement and surprise to engage customers, eating without the aid of cutlery has been applied in some restaurants around the world (Spence & Piqueras-Fiszman, 2014). For example, at restaurant Alinea in Chicago, one of the previous menus included a helium-filled candy balloon which was left inflated on the table with the inflated part at the level of the diner's head. The diner was then instructed to inhale the air inside the balloon while trying to eat the balloon with just their mouth.

1.3.3. Physiological factors influencing touch perception

Following the discussion of the importance of product and environmental factors influencing touch perception of texture, subject-dependent factors must be considered as well. In particular, the well-being and neurophysiological status of the participant are of critical importance. It has been determined that some illnesses may reduce oral and manual haptic sensitivity, as well as induce disproportionate reactions to haptic stimuli. Children with autistic disorders (AD) have been known to exhibit strong reactions to sensory cues, such as touch and other senses (Rogers & Ozonoff, 2005). The long-standing assumption for this abnormality is that a hypo-responsive child does not react to a sensory input of normal level due to their hypo-sensitivity, and same for those with hyper-responsivity (Güçlü et al., 2007). However, Güçlü et al. (2007) revealed that hyper- and hypo-responsivity in autistic children are not the result of a perceptual sensory problem, but rather more likely due to their inability to properly emotionally modulate the stimuli. Still, this illustrates that disorders can affect an individual's acceptance and attitude towards a product as assessed through the sense of touch. Additionally, impaired individuals have also been shown to develop higher sensitivity and discriminatory ability for a sensory sense to compensate for a reduced sensitivity in one sense. In a study examining the tactile sensitivities of blind, deaf, and unimpaired individuals, visually impaired participants displayed higher tactile sensitivity than the other two groups (Barbacena et al., 2009). The researchers attributed this to these individuals naturally acquiring higher sensitivity to the sense of touch as a substitute for vision from important daily activities, such as reading Braille texts. Through a series of extensive studies, it was determined that this increased tactile acuity of blind individuals is not due to tactile experience reading Braille texts, but rather due to "brain plasticity" due to lack of vision (Goldreich & Kanics, 2003; Goldreich & Kanics, 2006). "Brain plasticity" refers to the theory that brain can be reorganized as a function of experience. Consequently, blind individuals retain better tactile acuity throughout their lives, although this ability will still decline with age, as with unimpaired individuals (Stevens et al., 1996; Legge et al., 2008).

In discussing touch perception, one must acknowledge the importance of the neurophysiological aspect of the subjects. In regard to skin touch sensitivity, the temperature of the skin must be considered. The skin and subdermal tissue are extensively involved in the homeostatic regulation of body temperature (Saxena, 1983). This is done by the modification of blood flow through various skin tissues and by perspiration. Factors such as specific heat of the tissue, tissue thermal conductivity, mass flow of blood, and temperature of blood cause variations in skin surface temperature, which have been shown to affect skin vibratory sensitivity (Bolanowski & Verrillo, 1982). In another study, increasing skin temperature from 10°C to 43°C results in a notable increase in perceived roughness of grooved plates, in particular those with groove widths of less than 0.5mm (Green et al., 1979). Another important subject-dependent factor is the participant's demographics, such as age and gender. Age has been widely studied, and the influence on pressure and vibrotactile sensitivity, and spatial acuity have been determined (Thornbury & Mistretta, 1981; Desrosiers et al., 1999; Verrillo et al., 2002). However, the most relevant to the present study would be the effect of age on texture perception. Interestingly, although studies on touch sensitivity and spatial resolution have reported substantial decline in the abilities of older participants, studies on texture perception appear to have yielded comparable results between old and young participants (Tremblay et al., 2002; Bowden & McNulty, 2013). Thus, it can be postulated that multiple tactile sensations combine to relay sufficient information to the somatosensory cortex to result in successful texture discrimination. With regard to the effects of gender, Kozlowska (1998) performed a study involving over 1500 participants of a wide range of ages, in which she revealed that women exhibit higher tactile sensitivity and proposed a possible explanation of women having thinner skin as a result of hormonal conditioning. More recent studies have revealed another factor influencing touch perception: the subject's posture. Zampini et al. (2005) demonstrated that when participants are made to change their posture from anatomical posture to interleaved posture during a directional tactile discrimination procedure, they experience a decrease in their accuracy.

Oral sensory perception of food is the combination of emergent sensations from mucosa, teeth, muscles, temporomandibular joint, and the ears during oral processing (Heath & Prinz, 1999). In surface texture identification, sensations from mucosa are likely to provide the most important information (Chen, 2007). Contrary to the decline in hand-feel touch acuity with increasing age, oral touch acuity does not appear to decline with age (Lukasewycz & Mennella, 2012). The process of mastication follows the journey of food from front of the mouth to post-canine teeth, then through a mechanical breakdown by teeth whereby the food is fragmented into pieces, and finally transported back to the oropharynx where bolus is created and stored until it is swallowed (Hiiemae & Palmer, 1999). As described, mastication is a complex process combining various intra-oral movements. In a study examining the effects of tongue movements on food perception, de Wijk et al. (2003) found that modifying participant mastication behavior resulted in generally increased intensity of food attributes with increasing movement complexity. The study also found that low-fat products may be more sensitive to behavior modifications than high-fat products, and certain sensations, such as creaminess, are more affected by this than others. In addition, tongue movements also influence the physical properties of food, such as viscosity (Prinz & de Wijk, 2004; de Wijk et al., 2006). The more tongue movement performed during mastication, the more salivary amylase and saliva becomes mixed with the food product, resulting in a decrease of viscosity. From this study, it is also possible to observe that saliva also has a great impact on food texture perception. Salivary amylase hydrolyzes starch-producing sugars and oligosaccharides, which alters oral texture perception (de Wijk et al., 2004). It has been shown by de Wijk et al. (2004) that the addition of extra amylase or an amylase inhibitor to a starch-based custard resulted in an increase of perceived creaminess, thickness, and melting feelings up to 100% when enzymatic breakdown was minimized. Another factor influencing oral texture perception is the oral processing rates or how fast oral processing occurs for food breakdown and evaluation. Trained panelists may focus more on oral sensations and as a consequence, slows down their oral processing rate (González et al., 2002). This was revealed to be an influencing factor by Brown et al. (1994), who investigated the chewing patterns of 52 subjects for raw carrots using electromyography and categorized them based on their chewing efficiency. The results of the study demonstrated differences in perceived magnitude of firmness and rubberiness in model foods between the chewing pattern groups.

1.3.4. Psychological factors influencing touch perception

Besides individual differences in physiological sensitivities, touch perception is also notably influenced by differences in an individual's social and psychological factors, i.e. experiences, culture, mood, and personality. Food is a part of an individual's cultural identity (McWilliams, 2006). In many cultures, food is a hallmark in many essential traditions, e.g. turkey, stuffing, and gravy in American Thanksgiving dinners. Additionally, people also develop preferences for food characteristics based on social interactions, such as parental influences and peer relationships (Muñoz & Civille, 1987). The willingness to accept new foods of different taste and texture in childhood are influenced by strong-to-moderate genetic heritability, as well as early repeated exposure to those foods (Ruiz et al., 2010). Since infants are predisposed to foods that elicit pleasing sensations, such as sweet tastes, and reject others that do not, like sour and bitter tastes (Birch, 1999), this exposure to new foods is especially important for the development of food texture preference. Generally, people more frequently consume and are more familiar with foods that exhibit characteristics that they prefer, which leads to the formation of expectations and familiarity bias. When consumers are presented with a food product, they expect certain characteristics based on their previous experiences with that product, which are unconsciously compared to the real attributes of the product, resulting in their confirmation or disconfirmation (Deliza & MacFie, 1996). Whilst numerous studies have investigated the influences of social and cultural aspects on acceptance, attitude, and flavor/taste of food, there has been very little studies focusing on food texture, whether intra-orally or extra-orally. Thus far, those that attempted to reveal a difference in texture perception cross-culturally have provided mixed results. A study by Tu et al. (2010) showed that whilst there was a cross-cultural difference in aroma attributes for soy yogurts, there was none for texture and taste for Vietnamese and French panelists. However, Prescott et al. (1997) found that Australian panelists perceived ice cream samples to be creamier than Japanese panelists, suggesting a cross-cultural effect.

Another important subject-dependent factors to touch perception are emotions and personal tendencies. Peck and Childers (2003) have famously created the “Need-for-Touch” (NFT) scale, which measures a person’s motivation or preference to touch objects (Krishna, 2011). The scale consists of 2 sub-scales, instrumental and autotelic, and 12 total questions. Instrumental NFT measures a person’s tendency to touch for a specific objective, e.g. to make a judgment for purchase, and includes questions such as “The only way to make sure a product is worth buying is to actually touch it”. Autotelic NFT gauges touch compulsivity or tendency to touch for the sake of touching alone, and includes questions such as “Touching products can be fun”. This scale has been successfully in a few studies used to discern individual differences in perception based on different need-for-touch levels. As in the study done by Krishna and Morrin (2008), the results showed that depending on the individuals’ NFT, nondiagnostic haptic cues, such as the textural feel of the container, may not be as influential to their perception and evaluations. Additionally, it has been widely accepted that certain emotions can induce enhancement of sensory perception. For example, anger can increase finger temperature, whereas fear can decrease it (Levenson et al., 1991), which has been shown to ultimately affect tactile vibratory sensations (Bolanowski & Verrillo, 1982). The study done by Kelley and Schmeichel (2014) showed the first evidence of the impacts of emotional states on tactile manual sensitivity. In this study, participants who experienced fear appeared to exhibit decreased tactile fingertip sensitivity compared to those who experience neutral condition and anger.

2. Influences of touch perception on other sensory perceptions

Humans assess objects they encounter and their surroundings via several senses simultaneously (Driver & Spence, 2000). The primary focus of the present study, the sense of touch, engages the involvement of multisensory integration and perception (Lederman, 1982). Generally, touching an object provides information of its geometric (e.g. shape, size, orientation, and curvature) and material (e.g. temperature, compliance, texture, and weight) properties (Whitaker et al., 2008). Product attributes perceived by the sense of touch are frequently applied to the assessment of the food surface texture, but the importance of texture in products, especially food, is often understated. Jowitt (1974) has defined texture as: “the attribute of a substance resulting from a combination of physical properties and perceived by the senses of touch (including kinesthesis and mouth feel), sight, and hearing”, proposing that texture is a multisensory product attribute. Below, cross-modality of touch with other sensory perceptions will be discussed.

2.1. Influences of touch perception on visual perception

When an individual touches an object, the sensation from that interaction activates several regions in the brain that are also responsive to visual cues (Amedi et al., 2005). Among those regions, one of the most widely studied is the lateral occipital complex (LOC), which are both object-selective in touch and vision (Stilla & Sathian, 2008). LOC has been shown to activate in response to haptic 3-D (Stilla & Sathian, 2008) and tactile 2-D (Prather et al., 2004) stimuli. Besides LOC, multiple loci along the intraparietal sulcus (IPS) have also been shown to respond in both visual and haptic discrimination of object features (Sathian et al., 2011). The established studies have demonstrated that both vision and touch can be used to assess textural attributes, particularly roughness, in abrasive papers (Lederman & Abbott, 1981). However, the extent to which information from one sense is used over the other depends greatly on the task (Lederman et al., 1986).

To date, most studies examining visuo-haptic integration have emphasized on the effects of visual cues on touch perception, whilst studies examining the effects of touch perception on visual perception have focused largely on crossmodal correspondance (CMC) and synaesthesia. CMC is described as "a perceptual or cognitive bias to pair certain aspects of different sensory dimensions" (Asad et al., 2016), whilst synaesthesia occurs when "a stimulus produces not only the sensory quality typically associated with that modality, but also a quality typically associated with another modality" (Martino & Marks, 2001). Typically, synaesthesia is used to describe individuals who experience unusually high cross-modal perception, e.g. seeing colors when hearing sounds (Ludwig & Simner, 2013). However, studies have shown that individuals who do not suffer from this condition (non-synaesthetes) also experience cross-modality, but not to the extent of synaesthetes (Ward et al., 2006). Of these numerous studies on cross-modal perceptions, some examined the association of touch perception on product attributes related to visual perception, such as color, luminance, and saturation. Ward et al. (2008) demonstrated that low color luminance is closely associated with roughness and high pressure to skin. In another study, Slobodenyuk et al. (2015) associated high color luminance with high smoothness, high softness, high elasticity, and low adhesion. Using a more realistic approach, Tu et al. (2013) evaluated consumer product expecations through the use of food product packaging of varying materials, and found that organic glass was perceived as bright. Additionally, while investigating crossmodal interactions between color and texture of food, Chylinski et al. (2015) discovered that blue color, in comparison to red, was associated with higher crunchiness ratings when the product was creamier (light yogurt with minimal crunchy almond flakes), but when the product was crunchier (light yogurt with high amount of crunchy flakes), blue was associated with reduced crunchiness ratings. As suggested from these studies, touch perception can affect visual perception, which is also used as a judgment of product quality. As such, the effects of touch-visual synaesthesia must be greatly considered in marketing, advertising, and product package design.

2.2. Influences of touch perception on auditory perception

Szczesniak (1963) has considered “sound effects, such as those occurring during eating of popcorn or celery, are related to the physical constitution of the food and should be considered as part of the overall textural effect”. As mentioned, the human perception of the world is multisensory. Neurological studies have shown that several regions in the brain are implicated in the multisensory integration of audio-tactile inputs (Schurmann et al., 2006). In particular, the posterior superior temporal gyrus (pSTG), adjacent posterior superior temporal sulcus (pSTS), and left fusiform gyrus (FG) are activated in response to multisensory object-recognition across audition and touch (Schurmann et al., 2006; Beauchamp et al., 2008; Kassuba et al., 2011). The exact contribution of each sensory modality to the activation of these regions for object recognition is still unclear, however.

The earliest studies on crossmodal correspondance (CMC) largely focused on the extent the sense of the word can be represented by its sound (sound symbolism), e.g. bang and fizz (Spence, 2011). A study on sound symbolism revealed that participants judged high-pitched sounding words like “mil” rather than lower-pitched sounding words like “mol” to be better fit to a white or small object than a black or large object (Sapir, 1929; Newman, 1933). Additionally, CMC studies have successfully demonstrated humans’ ability to associate tactile attributes with those of audio. The results of a study done by Eitan and Rothschild (2010) showed that high smoothness and softness can be associated with low sound intensity, low pitch, and flute sound (compared to violin), whilst high sharpness can be associated with high sound intensity and flute sound (compared to violin).

Regarding food and beverage products, there has been a growing interest on auditory product packaging design as more companies realize the power of sensory marketing. Krishna (2012) defined sensory marketing as “*marketing that engages the consumers' senses and affects their perception, judgment and behavior”.* The most common example of the effect of packaging design on the auditory perception can be seen in Snapple (owned by Dr. Pepper

Snapple Group Inc.) with its distinctive “Snapple pop”, which results in the association with the feeling of freshness as the bottle is opened (Spence & Wang, 2015). Most published studies have primarily focused on the effects of auditory perception on touch perception, but very few have investigated the direct influences of touch perception on auditory. However, considering the rapid growth of interest in packaging design, this area should be further researched to better incorporate crossmodality between touch and auditory in more areas of package design.

2.3. Influences of touch perception on olfactory perception

The role of olfactory perception on memory and learning has been extensively studied in the fields of psychology and more recently, sensory marketing. The primary reasoning for this close relationship is the physical and neural proximity of the systems responsible for response to olfactory stimuli (Krishna, 2012). The olfactory nerve is located two synapses away from amygdala, which has been determined to have a great role in emotion and emotional memory (Cahill et al., 1995), and three synapses away from hippocampus, which has been shown to play an even greater role in memory (Eichenbaum, 1996). This direct connection to memory makes the olfactory system unique compared to other senses (Krishna, 2012). Previous studies have shown that the ability to retain memory of scents previously encountered remains for quite a time, even years (Engen & Ross, 1973). With this information, more marketing strategies have attempted to integrate this crossmodal relationship to influence consumer perception and behavior. Existing research revealed that pleasant scents enhance product and store evaluations (Bosmans, 2006) and that congruent odors elicit more variety-seeking behavior and longer searching time in store (Mitchell et al., 1995).

Although plentiful crossmodal research on the effects of olfactory cues on haptic perception have been published, the effects of haptic on olfactory remain understudied. To elaborate on these existing research of olfactory effects on touch perception, Demattè et al. (2006) found that fabrics of varying softness levels were rated softer when presented with a lemon odor rather than animal-like odor, thereby illustrating that texture perception can be modulated by olfactory cues. In another study, feminine smell resulted in more positive haptic perceptions in smooth-textured paper, i.e. paper perceived to feel good in their hands and perceived to exhibit very good texture, whilst masculine smell resulted in more positive haptic perceptions in rough-texture paper (Krishna et al., 2010). Considering the established crossmodal relationship between olfactory and touch senses, it would be interesting to explore the influences of haptic cues on olfactory perception.

2.4. Influences of touch perception on gustatory perception

It has been believed by many that food and beverages taste better when served in a container with specific characteristics. As an example, wine experts believe that wine aroma and taste can differ depending on the glass it is served in. Indeed, the results of one study showed that sourness was most intense when presented in beaker-shaped glass (Hummel et al., 2003). Numerous other studies have also examined the validity of such statements and have suggested that the food and beverage perception are heavily affected by the feel and shape of the material (Spence et al., 2013). In one such study, it was found that when participants were not allowed to touch the flimsy cup material compared to when they were able to, water was rated higher in quality (Krishna & Morrin, 2008). Another observation suggesting this crossmodality relationship can be seen in individuals with congenital blindness, who have been shown to exhibit higher taste sensitivity and discriminative ability (Gagnon et al., 2013). Researchers have proposed that this may be due to their reliance on other senses when performing daily tasks, such as heavier emphasis on haptic cues for exploring their surroundings. Despite these existing studies, the effects of hand-feel haptic perception on taste remain largely unexplored.

Regarding effects of textural attributes in mouth on gustatory perception, the extent of such effects largely depends on the food ingredients, composition, and structure. For example, hard candy containing 15% gelatin was characterized as having an initial butter taste and strawberry, whilst soft candy containing 2% gelatin was described as sour, green, and strawberry (Saint-Eve et al., 2011). In another study, Harker et al. (2006) found that the oral breakdown of apple structure and the consequent juice release varied between hard and soft apples, even though the water contents were similar. This study found that juicy-type apples were rated consistently higher than non-juicy-type apples, thus illustrating that differences in apple matrix and textural attributes can influence the perceived sweetness.

2.5. Interactions between touch perceptions

The sense of touch can be perceived by humans from various parts of the human body. Regarding evaluation of food and beverage products, the mouth and hands are generally the body parts used to sense oral and manual haptic inputs and explore the product textural characteristics. It needs to be noted that tactile sensitivity does not necessarily indicate texture discrimination capability, which is important for food product evaluation. A study attempting to establish such correlation using measurements from the fingertips and tongue found that the tongue was slightly more sensitive in discriminating food texture, but no such correlation could be confirmed (Aktar et al., 2015). One former study presented “lolly stick” stimuli made from different materials (polystyrene, rough polystyrene, stainless steel, copper, rough copper, birch, balsa, glass and silicone) to panelists and compared the results of textural attributes perceived orally from the study to previous studies with emphasis on hand-feel texture perception (Howes et al., 2014). In studies concerning hand-feel touch perception, the dominant attributes are typically roughness, hardness, coldness, and slipperiness (Bergmann Tiest, 2010). However, in the study by Howes et al. (2014), roughness was shown to be less dominant than hardness and coldness. This comparison illustrated that different body parts used for texture perception may be better at sensing certain textural attributes better than the other, i.e. roughness is better explored by hand-feel, but hardness can be perceived equally well both orally and by hand-feel.

Currently, the effects of hand-feel touch perception on oral texture perception have been understudied. Of these few studies, Piqueras-Fiszman and Spence (2012) found that biscuits were rated as crunchier and harder when presented in a container with rough sandpaper finish compared to when they were presented in smooth-coated container. In addition, Barnett-Cowan (2010) demonstrated that perceived oral texture can be modulated by the hand-feel haptic perception. In his study, half of the participants were presented with half stale-half fresh pretzels and the other half presented with whole fresh or whole stale prezels. The blindfolded participants were then asked to hold one half of the pretzel and evaluate the other half orally. Another study varied the textural attributes of cups of different materials and examined the oral perception of the beverage samples (Schifferstein, 2009). The results of this study demonstrated the importance of consumer experience with containers, as this was shown to significantly affect many attributes related to their drinking experience. For certain attributes like warmness, consumers' rating of product attribute seemed to mimic their rating of container attribute. Considering the existing relationship between hand-feel and oral texture perceptions, particularly container-food interactions, this area would be interesting for further research and may provide more innovation and inspiration for novel designs of food packaging.

3. Influences of touch perception on emotional responses

Human interaction with their surroundings and other individuals are closely related to emotional responses. Emotions guide an individual's perspective of the world and regulate human behavior, making them integral to decision making (Norman, 2004). In addition, emotions and the consequent behavior function as means to indicate the wellbeing of the individual in their relationship to their surroundings (Desmet, 2010). For an individual to feel an emotion, he/she must grasp the situational meaning of perceived changes occurring in their interactions with their surroundings, and how these changes would influence their wellbeing. As such, the individual must appraise the occurrence's importance to their welfare. This appraisal differs from one individual to another since it acts as an intermediate between an event and emotions, and so, different individuals who experience the same event may perceive it differently and experience different emotions as a result. According to Ortony et al. (1988), there are three different types of appraisal: usefulness, pleasantness, and rightfulness. Combining these three appraisal types, an individual can determine whether a perceived change is beneficial to their wellbeing. For example, a situation can elicit good feelings because it is perceived to be useful, pleasurable, or rightful. Contrastingly, bad feelings can be elicited from a situation because it is perceived to be harmful, painful, or wrongful. Generally, empirical research on the effect of touch on interpersonal behavior has shown that touch communicates either positive emotional intentions, e.g. warmth and intimacy, or negative emotional intentions, e.g. pain or discomfort, depending on the context and that touch augments emotional effects from other sensory modalities (Knapp & Hall, 1997; Hertenstein & Keltner, 2006).

The mechanism in which an individual forms this emotional behavior also applies to their valuation and appraisal of a product. The emotional influence of a product on an individual is dependent on "its material qualities, purposes, meanings, expressions, and on what it does or fails to do" (Desmet, 2010). To assess the material quality, purpose, and the success of the product design, an individual must physically touch the product. In the field of product design, the physical features of a product, such as its weight, texture, and surface, compose its tangibility and can considerably influence a consumer's appreciation of its value (Ortony et al., 1988). In addition, touching a product also contributes to the complete experience of human-product interaction, where an individual is able to touch, feel, and receive affective pleasure from a tangible object. Peck and Childers (2003b) differentiated the two different types of information that an individual gains from haptic input via touching: instrumental and autotelic. Instrumental information relates to the intrinsic properties of a product and goal-directed evaluation of the performance of a product or its purchase, whilst autotelic information relates to the sensory experience and perceived affective appreciation of a product (Holbrook & Hirschman, 1982), which pertain to and elicit emotional responses from an individual.

4. Influences of touch perception on food choice and purchase intent

Perhaps with the rise of online shopping, touch has been historically the least studied sense in the field of marketing due to the lack of haptic product evaluation that can be done (Peck & Childers, 2008). Touch or haptic cues provide consumers with the material properties of a product, which includes information about its texture, softness, weight and temperature (Klatzky & Lederman, 1992; Klatzky & Lederman, 1993). It has been found in a study that if a material varies in one or more of these attributes and has more means that it can be examined, then a consumer will be more motivated to touch it for product judgment (Peck & Childers, 2004). In the study, products with the most variation in material properties (e.g. tennis racket, sweater) were touched longer than those with less variation and less means of evaluation (e.g. toothpaste, calculator). It has also been established that when consumers are able to haptically examine the product, the products with varied materials are most likely to be preferred (McCabe & Nowlis, 2003). However, if the shopping environment does not allow for haptic exploration, like in online shopping, then verbal description of the materialistic properties can reduce the difference in product preferences and effectively compensate for the lack of touch. Moreover, consumers' perception of ownership and valuation of an object can be modulated with mere touch or an imagery encouraging touch (Peck & Shu, 2009). In this study, participants were allowed to interact with the object and asked to imagine if they could take the object home to induce the imagery encouraging touch condition. According to the concept of maximum likelihood estimation (MLE), under the conditions of multisensory stimulation, the form of sensory input that carries the lowest degree of variance or the least "noise" will dictate or dominate the individual's perception over the inputs relayed by other sensory modalities (Spence & Gallace, 2011). Previous literatures have noted that skin seems to be particularly sensitive to affective responses, suggesting that based on the concept of MLE, touch dominates the overall multisensory affective response of a product (Field, 1998; Spence, 2002). This tendency to affect consumer acceptability would undoubtedly translate to higher likeliness of consumer purchase intent.

In addition, individuals can be categorized as high or low autotelics using the “Need-for-Touch” (NFT) scale created by Peck and Childers (2003a). High autotelics have been shown to more likely to engage in haptic exploration of a product by touch because they feel the need to, as well as be more persuaded by features that include a hedonic touch element (Peck & Childers, 2003a; Peck & Wiggins, 2006). In addition to the human tendency to impulsive behavior when a hedonic gratification is promised, researchers have also found that impulsive individuals are more inclined to touch a hedonic object (Ramanathan & Menon, 2001). This information, combined to the findings of Peck and Childers (2003a) where it was found that there was a positive significant correlation between autotelic individuals and purchase impulsiveness, suggests that high autotelics would be more likely to engage in impulsive purchase behavior (Peck & Childers, 2006). Regarding consumer perception of quality, Krishna and Morrin (2008) found that product liking of high autotelics are not as affected by non-diagnostic haptic cues, such as the material of the container. In this study, participants were presented with flimsy, low-quality plastic cup. Since consumers are more likely to purchase products that they like, this suggests that high autotelics are more likely to purchase products, even at lower-quality, if they were allowed to touch the product.

Research on touch perception of food product purchase and intent have been studied less extensively compared to other products, but it is a rapidly growing topic of interest. Consumers develop their expectations of food sensorial properties at the point of product appraisal, which involves visual and/or touch evaluation of product packaging (Guinard et al., 2001). If the expectations are not subsequently met by the sensorial qualities of the product, then consumer disconfirmation may occur, which consequently results in a change of product quality perception and purchase behavior (Deliza & MacFie, 1996). Disconfirmation can generate four possibilities of consumer behavior: (a) assimilation (ratings move towards expectations); (b) contrast (ratings move away from expectations); (c) generalized negativity (ratings decrease under all conditions of disconfirmation); (d) assimilation-contrast (at low disconfirmation, assimilation effect occurs, and at high disconfirmation, contrast effect occurs) (Deliza & MacFie, 1996; Ng et al., 2013). Confirmation of consumer expectations through sensory attribute evaluation usually yields in repeat product purchase, highlighting the importance of studies regarding the effects of both intrinsic sensorial attributes and extrinsic haptic cues of product packaging.

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CHAPTER 3. Influences of intrinsic factor (product temperature) on sensory perception of and emotional responses to coffee and green tea products

Abstract

Coffee and green tea are popular beverages consumed at both hot and cold temperatures. When people consume hot beverages concurrently with other activities, they may experience at different temperatures over the period of consumption. However, there has been limited research investigating the effects of product temperatures on emotional responses and sensory attributes of beverages. This study aimed to determine whether emotional responses to, and sensory attributes of, brewed coffee and green tea vary as a function of sample temperature. Using a check-all-that-apply (CATA) method, 157 participants (79 for coffee and 78 for green tea) were asked to evaluate either coffee or green tea samples served at cold (5 °C), ambient (25 °C), and hot (65 °C) temperatures with respect to emotional responses and sensory attributes. The results showed that sample temperature could have significant influences on emotional responses to, and sensory attributes of, coffee and green tea samples. More specifically, 6 and 18 sensory attributes of coffee and green tea samples, respectively, significantly differed with sample temperature. Beverage samples evaluated at 65 °C were characterized, regardless of activation/arousal level, by positive emotional responses terms and favorable sensory attributes. While beverages evaluated at 25 °C were associated more with negative emotional responses with low activation/arousal, those evaluated at 5 °C were more frequently characterized as having negative emotional responses with high activation/arousal. Sensory and emotional drivers of liking for both coffee and green tea differed both with sample temperature and gender. While both emotional responses and sensory attributes were identified as drivers of liking among females, only emotional responses were identified as drivers of liking among males. In conclusion, this study provides empirical evidence that both emotional responses to, and sensory attributes of, coffee and green tea beverages can vary with sample temperatures. To provide a better understanding of product characteristics, emotional responses to, and sensory attributes of, coffee or green tea beverages should be tested over a wider range of product temperatures.

Keywords: product temperature, sensory attribute, emotional response, coffee, green tea, gender

1. Introduction

Serving temperatures have been found to influence perceived intensities in basic taste solutions (Moskowitz, 1973; Bartoshuk et al., 1982; Lipscomb et al., 2016). Moreover, serving temperatures have been found to affect flavor/taste intensities and acceptances of various beverage products, including milk (Francis et al., 2005), wine (Zellner et al., 1988; Ross & Weller, 2008; Cliff & King, 2009), carbonated beverages (Cardello & Maller, 1982), and fruit-flavored beverages (Zellner et al., 1988). Those earlier studies, however, focused on quantification of intensity variation rather than qualification of sensory attributes. In other words, limited research has been done to examine whether detecability of certain sensory attributes can be affected by serving temperature of food or beverage products.

There has been no research regarding the effects of product temperatures on emotional responses to food or beverage products. Research investigating how product temperatures affect associations between emotional response and sensory perception of food or beverage products is also limited. However, three points are worth noting. First, food-evoked emotions play an important role in food acceptance and choice (King & Meiselman, 2010; Dalenberg et al., 2014; Gutjar et al., 2015). Furthermore, measuring both evoked emotions and sensory perception has been found to yield better understanding of consumer acceptance and preference toward foods or beverages (Samant et al., 2017). Second, thermal sensation (physical warmth or coldness) has been found to evoke emotional responses in humans (Kanosue et al., 2002; Sung et al., 2007; Williams & Bargh, 2008). Neuroimaging studies have revealed that when the body is exposured to different temperatures, significant changes of neural activations can be observed in the brain regions responsible for emotion processing, as well as thermal sensory perception (Kanosue et al., 2002; Sung et al., 2007; Rolls et al., 2008; Rolls, 2010). In a functional magnetic resonance imaging (fMRI) study conducted by Guest et al. (2009), liquid stimuli into the mouth at three different temperatures (5 °C, 20 °C, and 50 °C) increased neural activation in the brain regions associated with taste perception and reward, such as the insula, the somatosensory cortex, the orbitofrontal cortex, the anterior cingulate cortex, and the ventral striatum. In particular, pleasantness ratings of oral thermal stimuli were correlated with neural activations in the orbintofrontal cortex and the pregenual cingulate cortex. Finally, when people consume hot or cold meals concurrently with other activities like engaging in social conversations or performing office work, they may experience their meals over a wider range of food or beverage product temperatures because the temperatures decrease with time (Pramudya & Seo, 2017); it was reported that people generally consume a meal over a time interval between 10 and 60 min (Bell & Pliner, 2003).

This study aimed to determine whether and how temperatures of product samples affect emotional responses to, and sensory attributes of, brewed coffee and green tea beverages consumed at different temperatures: hot (65 °C), ambient (25 °C), and cold (5 °C) temperatures. These three values were chosen because those typically encounter during consumption of coffee and green tea beverages in daily life. More specifically, brewed coffee and green tea beverages are often consumed at hot temperatures; university students in the U.S. rated the range of 62.8 °C to 68.3 °C as ideal for consuming coffee beverages (Borchgrevinka et al., 1999). In addition, when people consume hot beverages while engaged in other activities (e.g., social conversation or office work) over a period of time, initially hot beverage temperature may fall to near ambient temperature (25 °C) during consumption. Finally, coffee and green tea continue to gain popularity as cold beverages (5 °C), e.g., iced coffee and iced matcha. Coffee and green tea beverages were specifically chosen as target products for this study because both are widely popular beverages consumed across numerous cultures worldwide, and are considered as “emotional” beverages that provide psychological comfort (Juneja et al., 1999; Cooper, 2012; Bhumiratana et al., 2014; Labbe et al., 2015).

Four research propositions were tested in this study. First, it was to be determined whether specific sensory attributes of coffee or green tea samples would be more dectable or dominant at hot, ambient, or cold temperatures (Research proposition 1), based on previous research regarding the effects of serving temperatures on intensities of sensory attributes in basic taste solutions, foods, and beverages (Moskowitz, 1973; Zellner et al., 1988; Ross & Weller, 2008; Kim et al., 2015; Lipscomb et al., 2016; Stokes et al., 2016; Steen et al., 2017). Due to temperature-dependent variations with respect to perceived intensity, certain attributes may be more dominant in coffee or green tea samples at hot, ambient, or cold temperature. Steen et al. (2017) evaluated brewed coffee samples at 6 serving temperatures ranging from 62 to 31 °C by measuring volatile compound profiles using gas chromatography-mass spectrometry and 8 flavor attributes (overall intensity, sour, bitter, sweet, tobacco, roasted, nutty, and chocolate) using descriptive sensory analysis. Intensities of four sensory attributes, i.e., overall intensity, bitter note, sweet note, and roasted flavor, were found to differ with sample temperatures. These attributes were especially associated with brewed coffee samples evaluated at temperatures of 50 °C or higher, possibly due to greater levels of aliphatic ketones, alkylpyrazines, some furans, and pyridines (Steen et al., 2017).

Second, it was to be determined whether specific emotions would be more highly evoked at hot, ambient, or cold temperature of coffee or green tea samples (Research proposition 2). Since sensory attributes have been found to be associated with emotional responses, temperature-induced variations in sensory attributes might be expected to affect emotional responses toward coffee or green tea beverage samples served at hot, ambient, and cold temperatures (Seo et al., 2009a; Ng et al., 2013; Chaya et al., 2015). Prior research has also demonstrated that warm or cold stimuli to the whole or partial body (e.g., hands or legs) can affect not only hedonic valence, but also emotional responses such as thermal comfort or discomfort (Kanosue et al., 2002; Sung et al., 2007; Rolls et al., 2008; Guest et al., 2009).

Third, based on previous research that found gender differences with respect to sensory perception (Doty et al., 1984; Larsson et al., 2003; Royet et al., 2003; Doty & Cameron, 2009; Ferdenzi & Roberts, 2013) and emotional processing (Wager et al., 2003; Seo et al., 2009a; Duerden et al., 2013), it was to be determined whether the effects of sample temperatures on sensory attributes and emotional responses would vary with gender (Research proposition 3). Females have been found to show better performances than males in odor memory, odor identification, and verbal fluency tasks (Larsson et al., 2003), possibly because of the greater number of neural activations of the left orbitofrontal cortex in females (Royet et al., 2003). Behavioral and neuroimaging studies have also demonstrated that males are more attentive to sensory aspects of emotional stimuli, while females are more attentive to subjective feelings of emotional stimuli (Orozco & Ehlers, 1998; Wager et al., 2003). A recent meta-analysis of neuroimaging studies associated with gender differences in emotional processing found that female processing of emotional stimuli occurs predominantly in the bilateral anterior insula as well as the mid and posterior insula on the left side, while males respond to emotional stimuli predominantly in the left anterior and mid insula as well as in the right posterior insula (Duerden et al., 2013). For this reason, it was anticipated that product temperature-dependent variation with respect to sensory attributes and emotional responses would be more pronounced in females than in males.

Finally, both sensory attributes and emotional responses have been found to play an important role in consumer acceptance of food or beverage products (Seo et al., 2009a; King & Meiselman, 2010; Piqueras-Fiszman & Spence, 2012; Dalenberg et al., 2014; Gutjar et al., 2015; Samant et al., 2017). It was therefore to be determined whether the impacts of sensory attributes and emotional responses on liking of coffee or green tea beverages would vary as a function of sample temperature (Research proposition 4a) and gender (Research proposition 4b). More specifically, if specific sensory attributes (Research proposition 1) and/or emotions (Research proposition 2) would be predominantly present at hot, ambient, or cold temperatures of coffee or green tea samples, the relative impact of individual sensory and emotional responses on liking of those samples may differ as a function of sample temperature. Moreover, if product temperature-induced sensory attributes and/or emotions differ by gender (Research proposition 3), the relative impacts of individual sensory and emotional responses on liking of coffee or green tea samples may differ between females and males.

The present study was designed to test the four research propositions for coffee (Study 1) and green tea (Study 2) beverages. This study was conducted in conformance with the Declaration of Helsinki for studies on human subjects. The protocol used in this study was approved by the Institutional Review Board of the University of Arkansas (Fayetteville, AR, USA). A written informed consent was obtained from each participant prior to the participation.

2. Study 1: Effects of sample temperatures on emotional responses to, and sensory attributes of, coffee beverage

2.1. Materials and methods

2.1.1. Participants

Through the consumer profile database of the University of Arkansas Sensory Service Center (Fayetteville, AR, USA), 79 coffee consumers (51 females and 28 males) ranging in age from 19 to 76 years [mean ± standard deviation (SD) = 39 ± 16] were recruited. Using a pre-screening survey, all participants self-reported that they habitually drink one or more cups of coffee with no added condiments, e.g., sugar, milk, and creamer, etc., and they prefer black coffee [i.e., greater than 5-points on a 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely)]. Participants also self-rated preferences for hot beverages [mean (± SD) = 7.9 (± 1.0) on a 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely)] and cold beverages [mean (± SD) = 7.8 (± 1.3)]. All participants were asked to refrain from eating, drinking (except water), and cigarette smoking for two hours prior to their participation to avoid potential influences of such activities on sensory perception (Cho et al., 2017).

2.1.2. Sample preparation and presentation

Grounded roasted coffee beans (Sugar Skull blend, Onyx Coffee Lab, Fayetteville, AR, USA) were brewed for 20 min using commercial coffee makers (Model DCC-2900, Cuisinart, East Windsor, NJ, USA) using a proportion of 90 g of ground coffee per 1,800-mL of spring water. A warm-up coffee sample (Lidl Essentials Coffee Classic, Lidl, Arlington, VA, USA) was prepared in the same manner. Brewed coffee was poured into a 3,000-mL stainless steel dispenser (Bunn, Springfield, IL, USA) to maintain its high temperature. Brewed coffee was served at three different temperatures: 65 °C, 25 °C, and 5 °C. Sample preparation to achieve temperatures of 25 °C and 5 °C involved placing coffee samples in a water bath to facilitate the cooling process. Each sample (55-mL) was presented in a 118-mL white Styrofoam cup identified with a three-digit code. Styrofoam cups were used to 1) minimize exposure of hands to thermal stimulation and 2) maintain target temperatures of coffee samples, and because Styrofoam cups are commonly used for serving both hot and cold beverages in the U.S.

2.1.3. Check-All-That-Apply (CATA) questions of emotion and sensory tests for coffee beverage

Since temperatures of brewed coffee samples can change quickly over time, rapid methods of emotion and sensory testing were used in this study. More specifically, participants were asked to check all appropriate terms, listed on either emotion check-all-that-apply (CATA) question or sensory CATA question. This method was found to be suitable for characterizing product temperature-dependent sensory-attribute variations in foods and beverages (Chapko & Seo, 2017; Pramudya & Seo, 2017). The emotion CATA question included 39 emotion terms from the EsSense Profile® (King &Meiselman, 2010). The sensory CATA question included 49 sensory attribute terms of coffee beverages generated by a previous study (Chapko & Seo, 2017). The following attributes were included: 21 aroma attributes (ashy, berry, bitter, brown sugar, burnt, cereal, chemical, chocolate, cocoa, fruity, green/vegetative, metallic, musty/earthy, nutty, papery/cardboard, pungent, roasted, skunky, sour, sweet, and tobacco); 3 appearance attributes (cloudy, oily, and transparent); 22 taste/flavor attributes (ashy, berry, brown sugar, burnt, cereal, chemical, chocolate, cocoa, fruity, green/vegative, metallic, musty/earthy, nutty, papery/cardboard, pungent, roasted, skunky, tobacco, bitter taste, salty taste, sour taste, and sweet taste); and 3 mouthfeel attributes (astringent, mouth coating, and viscous). For each sensory modality (i.e., aroma, appearance, flavor, taste, and mouthfeel), the terms were presented in alphabetical order to assist participants in quickly finding all attributes that they wanted to check. Lee et al. (2013) showed that consumer panelists took significantly less time to answer CATA questions when the terms were listed in a fixed order rather than in the Williams design presentation order. It was also found that the influence of CATA term order on consumer responses was minimal (Lee et al., 2013).

2.1.4. Procedure

This study was conducted at the University of Arkansas Sensory Service Center (Fayetteville, AR, USA). Prior to sample presentation, each participant was given a verbal introduction to the experimental protocol. Participants were then asked to taste brewed coffee (not that used in actual testing) as a warm-up sample and select all appropriate terms from those listed on the emotion CATA question that characterized their emotional responses evoked by experiencing the sample (Varela & Ares, 2012). The warm-up session allowed participants to not only better understand both protocol and emotion CATA question, but also to minimize any carry-over effect.

Following the warm-up session, participants were asked to taste coffee samples at three different temperatures, i.e., 65 °C, 20 °C, and 5 °C in a monadic sequential fashion. Participants were asked to drink from each sample as much as they wanted, then select (as in the warm-up session) all the terms on the emotion CATA question for characterizing their emotional responses to the sample. The presentation order of the three serving temperatures was randomized over a time interval of five minutes. Following the evaluation of the three samples with respect to emotional response, participants were given a 5-min break prior to a sensory testing session. During each break, spring water (Clear Mountain Spring Water, Taylor Distributing, Heber Springs, AR, USA) and unsalted crackers (Nabisco Premium Unsalted Tops Saltine Crackers, Mondelez Global LLC, East Hanover, NJ, USA) were provided as palate cleansers.

Prior to the main sensory testing session, participants were asked to taste and evaluate with respect to sensory attribute a warm-up sample of brewed coffee. They were asked to select all sensory terms listed on the sensory CATA question for characterizing sensory attributes of the sample. Participants were then asked to taste and evaluate coffee samples at the same three temperatures used in the emotion testing session. Participants were also asked to provide their overall liking of each sample on a 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely).

2.1.5. Statistical analysis

Data were analyzed using XLSTAT statistical software (Addinsoft, New York, NY, USA) and SPSS 24.0 for Windows™ (IBM SPSS Inc., Chicago, IL, USA). As previously proposed by Meyners et al. (2013) for an overall test of CATA data, chi-square testing was performed to determine whether the proportion of selections by participants for all terms of either the emotion CATA question or the sensory CATA question differed as a function of sample temperature or gender. To measure an effect size (or strength of association between two nominal variables) for chi-square test (or contingency table), Cramér's *V* (*V*) value was used. Cramér's *V* values, ranging from 0 (no association between the variables) to 1 (perfect association), of 0.1, 0.3, and

0.5 were considered small, medium, and large effect-sizes, respectively (Cohen, 1988; Kittler et al., 2007).

Cochran's Q test (Cochran, 1950), using the exact probability and distribution of the Q statistic (Patil, 1975), was also performed to determine whether the proportions of selection by participants for individual terms of either the emotion CATA question or the sensory CATA question differed by sample temperature or gender. If significant differences were found among the variables, post hoc multiple pairwise comparisons were performed using the Marascuilo procedure (Marascuilo & McSweeney, 1967). Correspondence analysis, based on chi-square distance, was used to visualize relationships of sample temperatures to emotional responses and sensory attributes. Significant terms of the CATA questions, as determined by the Cochran's Q test, were used for correspondence analysis.

A three-way analysis of variance (ANOVA) was performed treating "sample temperature" and "gender" as main effects and "participant" as a random effect. If a significant difference in means was indicated by the ANOVA, post-hoc comparisons between independent variables were performed using Tukey's Honest Significant Difference (HSD) method. To measure an effect size for ANOVA, a partial eta squared (ηp^2) value was used; the partial eta squared values of 0.01, 0.06, and 0.14 are considered small, medium, and large effect-sizes, respectively (Kittler et al., 2007; Velasco et al., 2014). Penalty-lift analysis (Williams et al., 2011; Meyners et al., 2013) was also conducted to identify positive and negative drivers of overall liking among emotion and sensory attribute terms of coffee samples. Mean differences in overall liking between the selected and unselected cases for individual emotions and sensory attributes were then determined. A positive (or negative) value for a particular attribute indicates the mean liking of participants who selected that attribute was greater than the mean liking of those who did not (Meyners et al., 2013). A statistically significant difference was defined to exist when $P < 0.05$.

2.2. Results

2.2.1. Overall effects of sample temperatures on emotional responses and sensory attributes

To determine whether the proportions of selection by participants for all terms of either the emotion CATA question or the sensory CATA question differed as a function of sample temperature, the data were collapsed into the three temperature conditions: 5 °C, 25 °C, and 65 °C. Chi-square testing revealed that the proportions of selection by participants for all emotion terms significantly differed among the three temperatures evaluated in this study (χ^2 = 65.24, P < 0.001, V = 0.08): 5 °C (12.3%), 25 °C (12.7%), and 65 °C (18.8%). More specifically, participants selected greater numbers of emotion terms when they evaluated coffee samples at 65 °C than at 5 °C or 25 °C, but the effect size (Cramér's V value) was low. In addition, the selection proportions for all sensory terms were not significantly different among the three temperature conditions (P = 0.91): 5 °C (18.6%), 25 °C (18.4%), and 65 °C (18.8%).

Table 1 is a contingency table showing the proportions of selection by participants for individual emotion terms of coffee samples served at 5 °C, 25 °C, and 65 °C. A higher proportion, i.e., closer to 1.00, indicates that the term was more frequently chosen by participants. Cochran's Q test revealed that 16 emotion terms of coffee samples significantly differed as a function of sample temperature: “active”, “bored”, “calm”, “disgusted”, “eager”, “energetic”, “glad”, “good”, “happy”, “nostalgic”, “peaceful”, “pleasant”, “pleased”, “satisfied”, “warm”, and “wild”. In addition, **Table 2** is a contingency table showing the proportions of selection for individual sensory-attribute terms of coffee samples served at the three temperatures. Cochran's Q test revealed that 6 sensory attributes of coffee samples significantly differed with respect to sample temperature: “pungent aroma”, “roasted aroma”, “metallic flavor”, “roasted flavor”, “skunky flavor”, and “bitter taste”.

A bi-plot of correspondence analysis (**Figure 1**), drawn by the above 16 emotional responses and 6 sensory attributes, visualizes associations of sample temperatures with emotional responses and sensory attributes. More specifically, a coffee sample tasted and evaluated at 65 °C was characterized more with emotion terms, “happy”, “pleased”, “satisfied”, “warm”, as well as sensory term “roasted flavor”. A coffee sample evaluated at 25 °C was characterized more by emotion terms “bored” and “wild”, and by sensory attribute terms “roasted aroma” and “bitter taste”. Finally, a coffee sample consumed at 5 °C was characterized more with not only sensory attribute terms “pungent aroma”, “metallic flavor”, and “skunky flavor”, but also by emotion terms of “active”, “disgusted”, and “energetic”. These results support the research propositions that specific sensory attributes (Research proposition 1) or emotional responses (Research proposition 2) can be variously dominant at hot, ambient, or cold temperature of coffee samples.

2.2.2. Gender comparion with respect to the effects of sample temperatures on emotional responses and sensory attributes

To determine whether the proportions of participant selection for all terms of either the emotion CATA question or the sensory CATA question differed as a function of gender, the data were collapsed into two groups: females and males. Chi-square testing revealed that the proportions of selection by participants for all emotion terms were not significantly different between female (14.4%) and male (14.9%) participants (P = 0.51). In addition, the proportions of selection for all sensory terms were not significantly different between female (18.9%) and male (18.1%) participants (P = 0.28).

Cochran’s Q test revealed that sample temperatures significantly affected 6 emotional responses (“disgusted”, “happy”, “pleased”, “satisfied”, “warm”, and “wild”) and 1 sensory attribute (“roasted flavor”) of brewed coffee samples from both female and male participants. However, the effects of sample temperatures on emotional responses to, and sensory attributes of, coffee samples were found to be different for 10 emotions and 6 sensory attributes. More specifically, for female participants, but not male participants, sample temperatures were found to affect 7 emotional responses (“active”, “bored”, “calm”, “glad”, “good”, “mild”, and “peaceful”) and 3 sensory attributes (“skunky aroma”, “skunky flavor”, and “bitter taste”) of coffee samples. In contrast, for male participants, but not female participants, sample temperatures were found to influence 3 emotional responses (“nostalgic”, “pleasant”, and “worried”) and 3 sensory attributes (“burnt aroma”, “sour taste”, and “viscous”) of coffee samples. These results support the research proposition that the effects of sample temperatures on sensory attributes and emotional responses vary with gender (Research proposition 3).

2.2.3. Impacts of emotional responses and sensory attributes on liking of coffee samples as a function of sample temperature and gender

A three-way ANOVA, treating “sample temperature” and “gender” as main effects and “participant” as a random effect, revealed that participants liked coffee samples evaluated at 65 °C (mean ± SD = 6.0 ± 1.9) more than those evaluated at 25 °C (4.2 ± 2.0) or 5 °C (4.0 ± 2.3) ($P < 0.001$, $\eta p^2 = 0.30$). However, there was neither a significant effect related to gender ($P = 0.83$), nor interaction between sample temperature and gender ($P = 0.70$).

Penalty-lift analysis identified drivers of liking with respect to emotional responses and sensory attributes at three different coffee sample temperatures. Overall, when considering all coffee samples tasted at three different temperatures, “pleased”, “satisfied”, “pleasant”, “warm”, “calm”, and “energetic” emotions, as well as “roasted flavor” attribute were identified as positive drivers of liking, while “disgusted” emotion, “bitter taste”, and “metallic flavor” attributes were determined as negative drivers of liking [**Figure 2(A)**].

When coffee samples were consumed and evaluated at 65 °C, “pleasant”, “pleased”, and “satisfied” emotions as well as “roasted flavor” attribute were identified as positive drivers of liking, while a “sour taste” attribute was determined as a negative driver of liking [**Figure 2(B)**]. In addition, not only “calm” emotion, but also “sweet aroma”, “oily”, “roasted flavor”, and “astringent mouthfeel” attributes were determined as positive drivers of liking, while both the “disgusted” emotion and the “pungent flavor” attribute were identified as negative drivers of liking for coffee sample evaluated at 25 °C [**Figure 2(C)**]. Finally, when coffee samples were evaluated at 5 °C, “interested”, “active”, and “energetic” emotions, as well as the “roasted flavor” attribute were identified as positive drivers of liking, while both the “disgusted” emotion and the “burnt flavor” attribute were determined as negative drivers [**Figure 2(D)**]. These results support the research proposition that the impact of sensory attributes and emotional responses on liking of coffee samples varies as a function of sample temperature (Research proposition 4a).

Gender was found to differ with respect to positive and negative drivers of liking for coffee samples tasted at three different temperatures. For female participants, not only “satisfied”, “pleased”, “calm”, “good”, “happy” emotions, but also the “roasted flavor” attribute was identified as positive drivers of liking, while the “disgusted” emotion and the “bitter taste” attribute were determined as negative drivers of liking [**Figure 3(A)**]. For male participants, there were only emotion-related drivers of liking, i.e., “pleased”, “warm”, and “satisfied” emotions as positive drivers and the “disgusted” emotion as a negative driver [**Figure 3(B)**]. These results support the research proposition that the impacts of sensory attributes and emotional responses on liking of coffee samples vary as a function of gender (Research proposition 4b).

3. Study 2: Effects of sample temperatures on emotional responses to, and sensory attributes of, green tea beverage

3.1. Materials and methods

3.1.1. Participants

Seventy-eight green tea consumers (55 females and 23 males) ranging in age from 18 to 80 years [mean ± standard deviation (SD) = 41 ± 17] were recruited. Through a pre-screening survey, all participants self-reported that they weekly drink one or more cups of green tea without any condiments and like green tea (i.e., higher than 5-point on a 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely). In addition, participants self-rated that they like both hot beverages [mean (± SD) = 7.9 (± 1.1) on a 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely)] and cold beverages [mean (± SD) = 8.2 (± 0.9)]. All participants were asked to refrain from eating, drinking (except water), and cigarette smoking for two hours prior to their participation.

3.1.2. Sample preparation and presentation

For green tea samples, green tea bags (Korean Organic Green Tea, Nokchawon Co. Ltd., Seoul, Korea) were steeped with boiled water in a proportion of 2 bags per 200-mL of spring water for 3 min. For a warm-up sample, another green tea product (Sun Nokcha, Haioreum, Lyndhurst, NJ, USA) was steeped in the same manner. After steeping, the green tea was poured into a 3,000-mL stainless steel dispenser (Bunn, Springfield, IL, USA) to maintain its high temperature. Green tea samples were randomly presented at three different temperatures: 65 °C, 25 °C, and 5 °C in a monadic sequential fashion. As for the coffee samples, sample preparation to temperatures of 25 °C and 5 °C required green tea samples to be placed in a water bath to facilitate the cooling process. Each green tea sample (55-mL) was presented in a 118-mL white Styrofoam cup identified with a three-digit code.

3.1.3. Check-All-That-Apply (CATA) questions of emotion and sensory tests for green tea

An emotion CATA question, including 39 emotion terms of the EsSense Profile® (King & Meiselman, 2010), was used for measuring emotional responses evoked by drinking green tea samples presented at the three serving temperatures. In addition, a sensory CATA question of green tea included 57 sensory attribute terms, based not only on previous research regarding descrptive sensory analyses of green tea (Ikeda et al., 2004; Ito and Kubota, 2005; Lee and Chambers, 2007; Lee et al., 2008; Castiglioni et al., 2015), but also on descriptions by consumer and descriptive panelists. The following attributes were included: 21 aroma attributes (animalic, ashy, beany, bitter/tannic, burnt, chemical, citrus, earthy/dirty, fermented, floral, fruity, grainy, grassy/cut grass, hay-like, herbal/herb-like, long lasting, metallic, mild/mellow, nutty, roasted, and pungent); 6 appearance attributes (brown color, clear, green color, sediment, turbid, and yellow color); 23 taste/flavor attributes (animalic, ashy, beany, burnt, chemical, citrus, earthy/dirty, fermented, floral, fruity, grainy, grassy/cut grass, hay-like, herbal/herb-like, long lasting, mild/mellow, nutty, roasted, and pungent); 5 mouthfeel attributes (astringent, metallic, mouth coating, smooth, and viscous); and 2 aftertaste attributes (bitter aftertaste and sour aftertaste).

3.1.4. Procedure

Both emotion and sensory tests of green tea samples were conducted in the same manner as described in Study 1 of coffee samples.

3.1.5. Statistical analysis

Data was analyzed in the same manner as described in Study 1 of coffee samples.

3.2. Results

3.2.1. Overall effects of sample temperatures on emotional responses and sensory attributes

To determine whether the proportions of selection by participants for all terms of either the emotion CATA question or the sensory CATA question differed as a function of sample temperature, the data were collapsed into the three temperature conditions: 5 °C, 25 °C, and 65 °C. Chi-square testing revealed that the proportions of selection by participants for all emotion terms significantly differed among green tea samples evaluated at the three temperatures (χ^2 = 27.81, P < 0.001, V = 0.06): 5 °C (12.8%), 25 °C (12.7%), and 65 °C (16.8%). More specifically, participants selected a greater number of emotion terms when evaluating green tea at 65 °C than at 5 °C or 25 °C, but the effect size (Cramér's *V* value) was low. In addition, the proportions of selection for all sensory terms did not significantly differ among green tea samples evaluated at the three temperatures ($P = 0.90$): 5 °C (17.1%), 25 °C (17.1%), and 65 °C (17.4%).

Table 3 is a contingency table showing the proportions of participant selection for individual emotion terms of green tea samples tasted and evaluated at 5 °C, 25 °C, and 65 °C. Cochran's Q test revealed that 19 emotion terms of green tea samples significantly differed as a function of sample temperature: "active", "adventurous", "affectionate", "bored", "calm", "darling", "disgusted", "energetic", "good", "joyful", "loving", "nostalgic", "peaceful", "pleasant", "polite", "satisfied", "secure", "warm", and "wild". In addition, **Table 4** is a contingency table that shows the proportions of selection for individual sensory terms of green tea samples evaluated at the three temperatures. Cochran's Q test revealed that 18 sensory attributes of green tea samples significantly differed with respect to sample temperature: "animalic aroma", "floral aroma", "herbal/herb-like aroma", "roasted aroma", "pungent aroma", "brown color", "green color", "yellow color", "mild/mellow flavor", "nutty flavor", "roasted flavor", "pungent flavor", "bitter taste", "sour taste", "sweet taste", "astringent mouthfeel", "smooth moutfeel", and "bitter aftertaste".

A bi-plot of correspondence analysis (**Figure 4**), drawn by the above 19 emotional responses and 18 sensory attributes, visualizes associations of sample temperatures with emotional responses and sensory attributes. More specifically, green tea sample tasted and evaluated at 65 °C was more characterized with emotion terms "affectionate", "calm", "good", "loving", "nostalgic", "peaceful", "pleasant", "satisfied", "secure", and "warm", as well as sensory terms "floral aroma", "herbal/herb-like aroma", "roasted aroma", "brown color", "mild/mellow flavor", "roasted flavor", and "sweet taste". Green tea samples evaluated at 25 °C were more characterized by emotion terms "bored", "disgusted", and "polite" and the sensory term "bitter taste". Finally, green tea samples evaluated at 5 °C were characterized by emotion terms "active", "adventurous", "energetic", "joyful", and "wild", as well as sensory terms "animalic aroma", "pungent aroma", "green color", "pungent flavor", "sour taste", "astringent mouthfeel", and "bitter aftertaste". These results support the research propositions that certain sensory attributes (Research proposition 1) or emotional responses (Research proposition 2) can be more dominant at hot, ambient, or cold temperature of green tea samples.

3.2.2. Gender comparion with respect to the effects of sample temperatures on emotional responses and sensory attributes

To determine whether the proportions of participant selection for all terms of either the emotion CATA question or the sensory CATA question differed as a function of gender, the data were collapsed into two groups: females and males. Chi-square testing revealed that the proportions of selection by participants for all emotion terms were not significantly different between female (13.7%) and male (15.1%) participants ($P = 0.07$). The proportions of selection for all sensory terms were also not significantly different between female (16.8%) and male (18.0%) participants ($P = 0.12$).

Cochran's Q test revealed that sample temperatures significantly affected 2 emotional responses ("disgusted" and "warm") and 5 sensory attributes ("animalic aroma", "roasted aroma", "brown color", "green color", and "yellow color") of green tea samples for both female and male participants. The effects of sample temperatures on emotional attributes and sensory attributes of green tea samples were found to differ with gender for 17 emotions and 8 sensory attributes. More specifically, for female participants, but not male participants, sample temperatures were found to affect 16 emotional responses ("active", "adventurous", "affectionate", "bored", "calm", "daring", "energetic", "good", "loving", "nostalgic", "peaceful", "pleasant", "satisfied", "secure", "tame", and "whole") and 7 sensory attributes ("herbal/herb-like aroma", "beany flavor", "mild/mellow flavor", "roasted flavor", "bitter taste", "smooth mouthfeel", and "bitter aftertaste") of green tea samples. In contrast, for male participants, but not female participants, sample temperatures were found to influence 1 emotional response ("understanding") and 1 sensory attribute ("sweet taste") for green tea samples. These results support the research proposition that the effects of sample temperatures on sensory attributes and emotional responses vary with gender (Research proposition 3).

3.2.3. Impacts of emotional responses and sensory attributes on liking of green tea as a function of sample temperature and gender

A three-way ANOVA, treating "sample temperature" and "gender" as main effects and "participant" as a random effect, revealed that hedonic ratings of green tea samples differed significantly with respect to sample temperaure ($P < 0.001$, $\eta p^2 = 0.22$): at 65 °C (mean ± SD = 6.3 ± 1.7) > at 25 °C (5.3 ± 1.8) > at 5 °C (4.6 ± 2.1). However, there were no significant effects of gender ($P = 0.33$), or interaction between sample temperature and gender ($P = 0.28$).

Penalty-lift analysis identified drivers of liking with respect to emotional responses and sensory attributes at three different temperatures of green tea sample. Overall, when considering all green tea samples experienced at three different temperatures, "warm", "satisfied", "good", "peaceful", "pleasant", and "calm" emotions, as well as "mild/mellow flavor", "smooth mouthfeel", and "brown color" attributes were identified as positive drivers of liking. Additionally, "bitter aftertaste", "bitter taste", "astringent mouthfeel", and "yellow color" attributes were identified as negative drivers of liking for green tea samples evaluated at different temperatures [**Figure 5(A)**].

Positive and negative drivers of liking with respect to emotional responses and sensory attributes were found at three different temperatures of green tea sample. When green tea samples were consumed and evaluated at 65 °C, not only "good" and "warm" emotions, but also "smooth mouthfeel", "roasted aroma", and "herbal/herb-like flavor" attributes were identified as positive drivers of liking, while the "bitter taste" attribute was determined as a negative driver of liking [**Figure 5(B)**]. When green tea samples were evaluated at 25 °C, only sensory attributes were identified as positive and negative drivers of liking: i.e., "mild/mellow flavor" and "smooth mouthfeel” attributes as positive drivers and “bitter taste” and “bitter aftertaste” as negative drivers of liking [**Figure 5(C)**]. In addition, when green tea samples were evaluated at 5 °C, not only the “free” emotion, but also “earthy aroma”, “smooth mouthfeel”, “herbal/herb-like flavor”, “grass/cut grass aroma”, and “mouth coating” attributes were identified as positive drivers of liking, while the “astringent mouthfeel” attribute was determined as a negative driver of liking [**Figure 5(D)**]. These results support the research proposition that the impacts of sensory attributes and emotional responses on liking of green tea samples vary as a function of sample temperature (Research proposition 4a).

Positive and negative drivers of liking for green tea samples tasted at three different temperatures were found to differ between female and male participants. For female participants, “pleasant”, “peaceful”, “warm”, “satisfied”, “calm”, and “good” emotions as well as “smooth mouthfeel”, “mild/mellow flavor”, and “brown color” attributes were idenitfied as positive drivers of liking. In addition, 4 sensory attributes, i.e., “bitter taste”, “bitter aftertaste”, “astringent mouthfeel”, and “yellow color”, were determined as negative drivers of liking [**Figure 6(A)**]. For male participants, only the “warm” emotion was identified as a positve driver of liking for green tea samples evaluated at different temperatures [**Figure 6(B)**]. These results support the research proposition that the impacts of sensory attributes and emotional responses on liking of green tea samples vary as a function of gender (Research proposition 4b).

4. Discussion

4.1. Variations with respect to emotional responses and sensory attributes as a function of sample temperature of coffee and green tea (Research propositions 1 and 2)

In most sensory studies of hot foods or beverages, samples have been evaluated in a temperature range at which those samples are typically consumed. For example, brewed coffee has been evaluated at one specific temperature between 75 °C and 55 °C (Nebesny & Budryn, 2006; Seo et al., 2009b, c; Bhumiratana et al., 2014; Di Donfrancesco et al., 2014). However, it is well-known that people consume hot foods or beverages over a wider range of temperature in everyday life, and certain beverages such as coffee and tea are often consumed at both hot and cold temperatures. Nevertheless, little attention has been paid to whether and how emotional responses as well as sensory attributes of hot foods or beverages can change as a function of their product temperatures.

The results from this study showed the dynamics of sensory attributes in both coffee and green tea samples with respect to serving temperatures of 65 °C, 25 °C, and 5 °C. Six and 18 sensory attributes of coffee and green tea samples, respectively, significantly differed in terms of sample temperature. Sample temperature-induced changes in sensory attributes of brewed coffee have been also observed in other studies (Stokes et al., 2016; Steen et al., 2017). In a recent study conducted by Stokes et al. (2016), “coffee flavor”, “roasted/burnt flavor”, and “full body” attributes were more associated with brewed coffee samples evaluated at higher temperatures of 60.4 °C, 70.8 °C, and 74.4 °C, while “earthy flavor” and “sour/acidic taste” were more related to those evaluated at lower temperatures of 31.0 °C and 41.1 °C. The present study to some extent showed similar results, that “roasted flavor” attribute of brewed coffee was more often identified at higher temperature (65 °C), while “pungent aroma”, “metallic flavor”, and “skunky flavor” attributes were more often characterized at lower temperature (5 °C). To the authors’ best knowledge, this study was the first to demonstrate that sensory attributes of green tea can vary with sample temperatures. Notably, green tea samples showed a greater number of significant sensory attributes affected by sample temperatures than did coffee samples, indicating that sensory attributes of green tea samples were more sensitive to temperature changes than those of coffee samples. Like coffee samples, green tea samples were more frequently characterized using desirable sensory attributes at higher temperature (65 °C), while those at lower temperatures (5 °C and 25 °C) were more often described using undesirable attributes.

Both coffee and green tea samples evaluated at higher temperature (65 °C) were more often characterized using emotions of positive valence with either high or low level of activation/arousal. In other words, beverage samples consumed at 65 °C more frequently evoked emotions of positive valence, such as “pleased”, “happy”, “satisfied”, and “warm”, etc., than did those consumed at either 25 °C or 5 °C. In addition, while beverage samples consumed and evaluated at 25 °C were characterized with emotions of negative valence with low level of activation/arousal, those evaluated at 5 °C were described with emotions of negative valence with high level of activation/arousal. Sample temperature-induced variation with respect to emotional responses might be associated with the dynamics of sensory attributes among the three temperature conditions of coffee or green tea samples. More specifically, the tetrachoric correlation analysis (Divgi, 1979) of sensory attributes and emotional responses for coffee samples revealed that “roasted flavor” and “mouth-coating” attributes showed positive correlation with emotions of positive valence, such as “warm” (roasted flavor: +0.54, mouth-coating: +0.34), “pleasant” (+0.49, +0.18), “satisfied” (+0.37, +0.20), “pleased” (+0.32, +0.22), and “happy” (+0.22, +0.13). In addition, “pungent aroma”, “chemical flavor”, “metallic flavor”, and “bitter taste” attributes positively correlated with emotions of high level of activation/arousal, such as “active” (pungent aroma: +0.08, chemical flavor: +0.18, metallic flavor: +0.17, and bitter taste: +0.22), “eager” (+0.14, +0.08, +0.21, and +0.09), and “energetic” (+0.28, +0.22, +0.18, and +0.15). These results were in agreement with previous studies that showed associations between sensory attributes and emotional responses (Seo et al., 2009a; Porcherot et al., 2010; Chaya et al., 2015). Furthermore, the tendency of warmer food or beverage products to evoke positive emotions illustrated the “temperature-premium effect”, where exposure to warm temperatures can increase a consumer’s evaluation of a product through the activation of the concept of positive emotional warmth in an individual, leading to greater positive reactions (Zwebner et al., 2013). Such an affective response of thermal stimuli could be explained by the increased neural activations in the brain regions associated with thermal sensation, sensory discrimination, emotional awareness and processing, and cognitive processing during direct exposure to warm stimulation (Sung et al., 2007).

4.2. Gender effects on the sample temperature-induced variations with respect to emotional responses to, and sensory attributes of, coffee and green tea (Research proposition 3)

Influences of sample temperatures on emotional responses and sensory attributes were observed in both female and male participants. Even though female and male participants did not exhibit any significant differences in terms of the proportions of selection by participants for either all emotion terms or all sensory terms, the results for female participants showed a larger number of emotion and sensory terms that significantly varied as a function of sample temperature compared to those of male participants. In other words, female participants displayed more consensus and less variable responses toward coffee and green tea samples presented at three different temperatures. This result might be related to earlier findings that female participants outperformed male participants with respect to odor sensitivity, odor identification, odor memory, and verbal proficiency (Doty et al., 1984; Larsson et al., 2003; Doty & Cameron, 2009; Ferdenzi & Roberts, 2013) although gender differences were not always observed. Moreover, a functional neuroimaging study conducted by Royet et al. (2003) found that while males showed neural activations in their bilateral insula and left piriform-amygdala regions during hedonic judgement of odors, females showed neural activations not only in the same regions as male participants, but also in left obitofrontal cortex related to odor identification, language, and emotion. Females have also been found to be more emotionally expressive toward foods and beverages than males (King et al., 2010; Jaeger & Hedderley, 2013).

4.3. Impacts of emotional responses and sensory attributes on likings of coffee and green tea (Research proposition 4)

Our findings support previous research suggesting that not only sensory attributes, but also emotional responses to some extent contribute to overall liking of foods and beverages (Seo et al., 2009a; Samant et al., 2017). Interestingly, drivers of liking with respect to emotional responses and sensory attributes were found to differ as a function of sample temperature in both coffee and green tea samples. For coffee samples, only the “roasted flavor” attribute was observed as a positive driver of liking at all three temperatures, while positive and negative drivers of liking changed at each temperature. “Roasted flavor” was more often identified at higher temperature (65 °C), possibly suggesting that participants increasingly like brewed coffee served at 65 °C the most. For green tea, the “smooth mouthfeel” attribute served as a positive driver of liking at all three temperatures. Like coffee samples, positive and negative drivers of liking for green tea samples varied with sample temperatures. Overall, among 57 sensory attributes of green tea samples, “mild/mellow flavor”, “smooth mouthfeel”, “brown color”, and “herbal/herb-like aroma” were found to be positive drivers of liking, while “bitter aftertaste”, “bitter taste”, “astringent mouthfeel”, and “yellow color” were negative drivers of liking. This result was in agreement with previous research where the U.S. consumers liked green tea samples with “mild flavor”, “no aftertaste”, “weak bitterness”, “flowery or fruity flavor”, and “brown flavor” notes (Lee et al., 2010). In addition, “sweet taste” and “roasted-related flavors” were considered to be drivers of liking for green tea samples (Lee et al., 2008). Building on previous research regarding sensory drivers of liking for green tea samples, this study added empirical evidence that emotions also serve as drivers of liking for green tea samples. Specifically, “warm”, “satisfied”, “good”, “peaceful”, “pleasant”, and “calm” emotions were found to play important roles in modulating liking of green tea samples served at different temperatures.

It is worth noting that drivers of liking for coffee or green tea samples were found to differ between female and male participants. While both emotional responses and sensory attributes contributed to likings of beverage samples among female participants, only emotional responses were considered as drivers of liking among male participants. This result might be related to previous findings that females outperformed males in odor sensitivity, odor identification, and odor memory tasks (Doty et al., 1984; Larsson et al., 2003; Doty & Cameron, 2009; Ferdenzi & Roberts, 2013). Females have also been found to perform better in taste sensitivity tasks than males (Michon et al., 2009). Since females could better detect sample temperature-induced changes in sensory attributes than males, sensory attributes might contribute to likings of coffee and green tea samples among female participants, but not among male participants.

5. Conclusion

To summarize, the results of this study showed that both emotional responses to, and sensory attributes of, coffee or green tea samples can vary with sample temperature. In other words, people may experience different sensory attributes and emotions with decreasing temperature of brewed coffee or green tea beverages, affecting their likings of those beverages. In addition, sample temperature-induced variations with respect to emotional responses and sensory attributes differed between female and male participants. Furthermore, while sensory attributes as well as emotional responses were found to be drivers of liking among female participants, only emotional responses were identified as drivers of liking among male participants. In conclusion, our findings provide empirical evidence that emotional responses to, and sensory attributes of, coffee and green tea beverages can vary as a function of sample temperature, and that such temperature-induced variations can differ by gender. Our findings emphasize the need to consider product temperature-induced dynamics of emotional responses and sensory attributes when evaluating food or beverage products that are temperature-sensitive. In other words, processors, manufacturers, sensory professionals, and marketers in the food industry should put more effort into exploring emotional responses to, and sensory attributes of, food or beverage products over the wider range of product temperatures that consumers may encounter in daily life. Such efforts may lead to both a better understanding of product characteristics and increases in consumer acceptance and purchase intent.

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Appendices

Table 1. A contingency table of the proportions of selection by 79 participants for individual emotion terms among coffee samples evaluated at the three different temperatures.

Terms[4]	Sample temperatures			*Q*-value[1]	*P*-value[2]	Cramér's *V* value[5]
	5 °C	25 °C	65 °C			
Active	0.25_{a}[3]	0.08_{b}	0.24_{a}	10.46	0.006	0.21
Bored	0.15_{ab}	0.24_{a}	0.09_{b}	6.14	0.02	0.17
Calm	0.13_{b}	0.25_{ab}	0.33_{a}	9.33	0.009	0.20
Disgusted	0.43_{a}	0.39_{a}	0.06_{b}	28.26	< 0.001	0.36
Eager	0.14_{a}	0.10_{a}	0.25_{a}	7.31	0.03	0.17
Energetic	0.29_{a}	0.13_{b}	0.28_{ab}	7.48	0.02	0.18
Glad	0.10_{ab}	0.05_{b}	0.23_{a}	10.76	0.004	0.22
Good	0.09_{b}	0.18_{ab}	0.33_{a}	15.39	< 0.001	0.25
Happy	0.14_{b}	0.11_{b}	0.33_{a}	13.63	< 0.001	0.24
Nostalgic	0.04_{b}	0.09_{b}	0.17_{a}	7.60	0.02	0.18
Peaceful	0.09_{b}	0.17_{b}	0.33_{a}	14.90	< 0.001	0.25
Pleasant	0.19_{b}	0.23_{ab}	0.37_{a}	7.24	0.03	0.17
Pleased	0.15_{b}	0.17_{b}	0.46_{a}	23.53	< 0.001	0.32
Satisfied	0.19_{b}	0.10_{b}	0.38_{a}	16.84	< 0.001	0.28
Warm	0.04_{b}	0.04_{b}	0.54_{a}	68.09	< 0.001	0.59
Wild	0.15_{a}	0.14_{a}	0.03_{b}	8.67	0.01	0.19

Cochran's Q test[1] (Cochran, 1950), using the exact probability[2] and distribution of the Q statistic (Patil, 1975), was performed to determine whether the proportions of participant selection for individual terms of emotion check-all-that-apply (CATA) question could differ by sample temperature.

[3] The proportions with different letters within each row represent a significant difference determined by post hoc multiple pairwise comparisons using the Marascuilo procedure (Marascuilo and McSweeney, 1967).

[4] Only significant terms, determined by Cochran's Q test, among 39 emotion terms of the EsSense Profile® (King and Meiselman 2010) were shown ($P < 0.05$).

[5] Cramér's *V* value was used to measure strength of association between two nominal variables (sample temperature × selected/unselected case) for the contingency table. Cramér's *V* values, ranging from 0 (no association between the variables) to 1 (perfect association), of 0.1, 0.3, and 0.5 were considered small, medium, and large associations, respectively (Cohen, 1988).

Table 2. A contingency table of the proportions of selection by 79 participants for individual sensory attribute terms among coffee samples evaluated at the three different temperatures.

Terms[4]	Sample temperatures			*Q*-value[1]	*P*-value[2]	Cramér's *V* value[5]
	5 °C	25 °C	65 °C			
Aroma						
Pungent	0.19_{a}[3]	0.06_{b}	0.14_{ab}	6.08	0.049	0.15
Roasted	0.35_{b}	0.52_{ab}	0.54_{a}	6.86	0.03	0.17
Taste/Flavor						
Metallic	0.33_{a}	0.22_{ab}	0.15_{b}	7.74	0.02	0.17
Roasted	0.33_{b}	0.37_{b}	0.63_{a}	18.00	< 0.001	0.27
Skunky	0.19_{a}	0.06_{b}	0.08_{b}	9.58	0.01	0.18
Bitter taste	0.84_{a}	0.84_{a}	0.67_{b}	8.05	0.02	0.19

Cochran's Q test[1] (Cochran, 1950), using the exact probability[2] and distribution of the Q statistic (Patil, 1975), was performed to determine whether the proportions of participant selection for individual terms of sensory check-all-that-apply (CATA) question could differ by sample temperature.

[3] The proportions with different letters within each row represent a significant difference determined by post hoc multiple pairwise comparisons using the Marascuilo procedure (Marascuilo and McSweeney, 1967).

[4] Only significant terms, determined by Cochran's Q test, among 49 sensory attribute terms were shown ($P < 0.05$).

[5] Cramér's *V* value was used to measure strength of association between two nominal variables (sample temperature × selected/unselected case) for the contingency table. Cramér's *V* values, ranging from 0 (no association between the variables) to 1 (perfect association), of 0.1, 0.3, and 0.5 were considered small, medium, and large associations, respectively (Cohen, 1988).

Table 3. A contingency table of the proportions of selection by 78 participants for individual emotion terms among green tea samples evaluated at the three different temperatures.

Terms[4]	Sample temperatures			*Q*-value[1]	*P*-value[2]	Cramér's *V* value[5]
	5 °C	25 °C	65 °C			
Active	0.32_{a}[3]	0.15_{b}	0.12_{b}	11.42	0.003	0.22
Adventurous	0.22_{a}	0.09_{b}	0.03_{b}	15.22	< 0.001	0.25
Affectionate	0.01_{b}	0.05_{b}	0.15_{a}	12.93	0.001	0.23
Bored	0.08_{b}	0.21_{a}	0.05_{b}	10.78	0.005	0.21
Calm	0.22_{b}	0.30_{ab}	0.44_{a}	8.75	0.01	0.19
Daring	0.22_{a}	0.08_{b}	0.08_{b}	11.52	0.003	0.20
Disgusted	0.21_{a}	0.24_{a}	0.03_{b}	19.00	< 0.001	0.26
Energetic	0.35_{a}	0.12_{b}	0.12_{b}	18.00	< 0.001	0.28
Good	0.17_{b}	0.22_{ab}	0.33_{a}	9.17	0.01	0.16
Joyful	0.18_{a}	0.05_{b}	0.15_{ab}	7.30	0.03	0.17
Loving	0.01_{b}	0.03_{b}	0.14_{a}	15.17	< 0.001	0.24
Nostalgic	0.06_{b}	0.03_{b}	0.19_{a}	12.64	0.002	0.24
Peaceful	0.14_{b}	0.22_{ab}	0.32_{a}	7.59	0.02	0.18
Pleasant	0.17_{b}	0.14_{b}	0.33_{a}	11.71	0.003	0.21
Polite	0.08_{b}	0.21_{a}	0.13_{ab}	6.91	0.03	0.15
Satisfied	0.14_{b}	0.14_{b}	0.35_{a}	14.63	< 0.001	0.24
Secure	0.08_{b}	0.10_{b}	0.24_{a}	12.25	0.002	0.21
Warm	0.03_{b}	0.09_{b}	0.63_{a}	78.39	< 0.001	0.63
Wild	0.15_{a}	0.12_{ab}	0.03_{b}	9.88	0.005	0.18

Cochran's Q test[1] (Cochran, 1950), using the exact probability[2] and distribution of the Q statistic (Patil, 1975), was performed to determine whether the proportions of participant selection for individual terms of emotion check-all-that-apply (CATA) question could differ by sample temperature.

[3] The proportions with different letters within each row represent a significant difference determined by post hoc multiple pairwise comparisons using the Marascuilo procedure (Marascuilo and McSweeney, 1967).

[4] Only significant terms, determined by Cochran's Q test, among 39 emotion terms of the EsSense Profile® (King and Meiselman 2010) were shown ($P < 0.05$).

[5] Cramér's *V* value was used to measure strength of association between two nominal variables (sample temperature × selected/unselected case) for the contingency table. Cramér's *V* values, ranging from 0 (no association between the variables) to 1 (perfect association), of 0.1, 0.3, and 0.5 were considered small, medium, and large associations, respectively (Cohen, 1988).

Table 4. A contingency table of the proportions of selection by 78 participants for individual sensory attribute terms among green tea samples evaluated at the three different temperatures.

Terms[4]	Sample temperatures			*Q*-value[1]	*P*-value[2]	Cramér's *V* value[5]
	5 °C	25 °C	65 °C			
Aroma						
Animalic	0.15_a[3]	0.00_b	0.01_b	22.17	< 0.001	0.30
Floral	0.12_b	0.13_b	0.27_a	9.17	0.01	0.19
Herbal/Herb-like	0.26_b	0.36_{ab}	0.50_a	12.70	0.002	0.21
Roasted	0.01_b	0.06_b	0.21_a	18.10	< 0.001	0.28
Pungent	0.14_a	0.04_b	0.01_b	12.00	0.002	0.23
Appearance						
Brown	0.12_b	0.30_b	0.83_a	84.93	< 0.001	0.62
Green	0.26_a	0.06_b	0.01_b	26.17	< 0.001	0.33
Yellow	0.80_a	0.78_a	0.19_b	72.10	< 0.001	0.57
Taste/Flavor						
Mild/Mellow	0.09_b	0.23_{ab}	0.35_a	15.05	< 0.001	0.25
Nutty	0.01_a	0.08_{ab}	0.12_a	7.54	0.03	0.17
Roasted	0.01_b	0.09_{ab}	0.14_a	10.13	0.005	0.19
Pungent	0.21_a	0.12_{ab}	0.04_b	11.04	0.004	0.21
Bitter taste	0.78_a	0.78_a	0.55_b	13.79	0.001	0.24
Sour taste	0.18_a	0.05_b	0.12_{ab}	7.50	0.03	0.16
Sweet taste	0.05_b	0.12_{ab}	0.21_a	9.33	0.008	0.19
Mouthfeel						
Astringent	0.32_a	0.28_{ab}	0.15_b	8.69	0.01	0.16
Smooth	0.31_{ab}	0.28_b	0.49_a	8.60	0.01	0.18
Aftertaste						
Bitter aftertaste	0.95_a	0.82_{ab}	0.73_b	13.27	0.001	0.24

Cochran's Q test[1] (Cochran, 1950), using the exact probability[2] and distribution of the Q statistic (Patil, 1975), was performed to determine whether the proportions of participant selection for individual terms of sensory check-all-that-apply (CATA) question could differ by sample temperature.

[3] The proportions with different letters within each row represent a significant difference determined by post hoc multiple pairwise comparisons using the Marascuilo procedure (Marascuilo and McSweeney, 1967).

[4] Only significant terms, determined by Cochran's Q test, among 57 sensory attribute terms were shown ($P < 0.05$).

[5] Cramér's *V* value was used to measure strength of association between two nominal variables (sample temperature × selected/unselected case) for the contingency table. Cramér's *V* values, ranging from 0 (no association between the variables) to 1 (perfect association), of 0.1, 0.3, and 0.5 were considered small, medium, and large associations, respectively (Cohen, 1988).

Figure Legend

Figure 1. A bi-plot drawn by the correspondence analysis in the associations of sample temperatures with emotional responses (red) and sensory attributes (blue) in coffee samples evaluated at the three temperatures (green squares). "A" and "F" next to sensory attribute term represent "aroma" and "flavor", respectively.

Figure 2. Mean drops in overall liking with respect to emotional responses and sensory attributes in coffee samples as a function of sample temperature: all temperatures (A), 65 °C (B), 25 °C (C), and 5 °C (D). "A", "F", and "M" next to sensory attribute term represent "aroma", "flavor", and "mouthfeel", respectively. Numerical value of each emotion or sensory attribute term represents a mean difference in overall liking between the selected and unselected cases; a positive (or negative) value for each term indicates an increase (or decrease) of overall liking between the selected and unselected cases.

Figure 3. Mean drops in overall liking with respect to emotional responses and sensory attributes in coffee samples as a function of gender: females (A) and males (B). "F" next to sensory attribute term represents "flavor". Numerical value of each emotion or sensory attribute term represents a mean difference in overall liking between the selected and unselected cases; a positive (or negative) value for each term indicates an increase (or decrease) of overall liking between the selected and unselected cases.

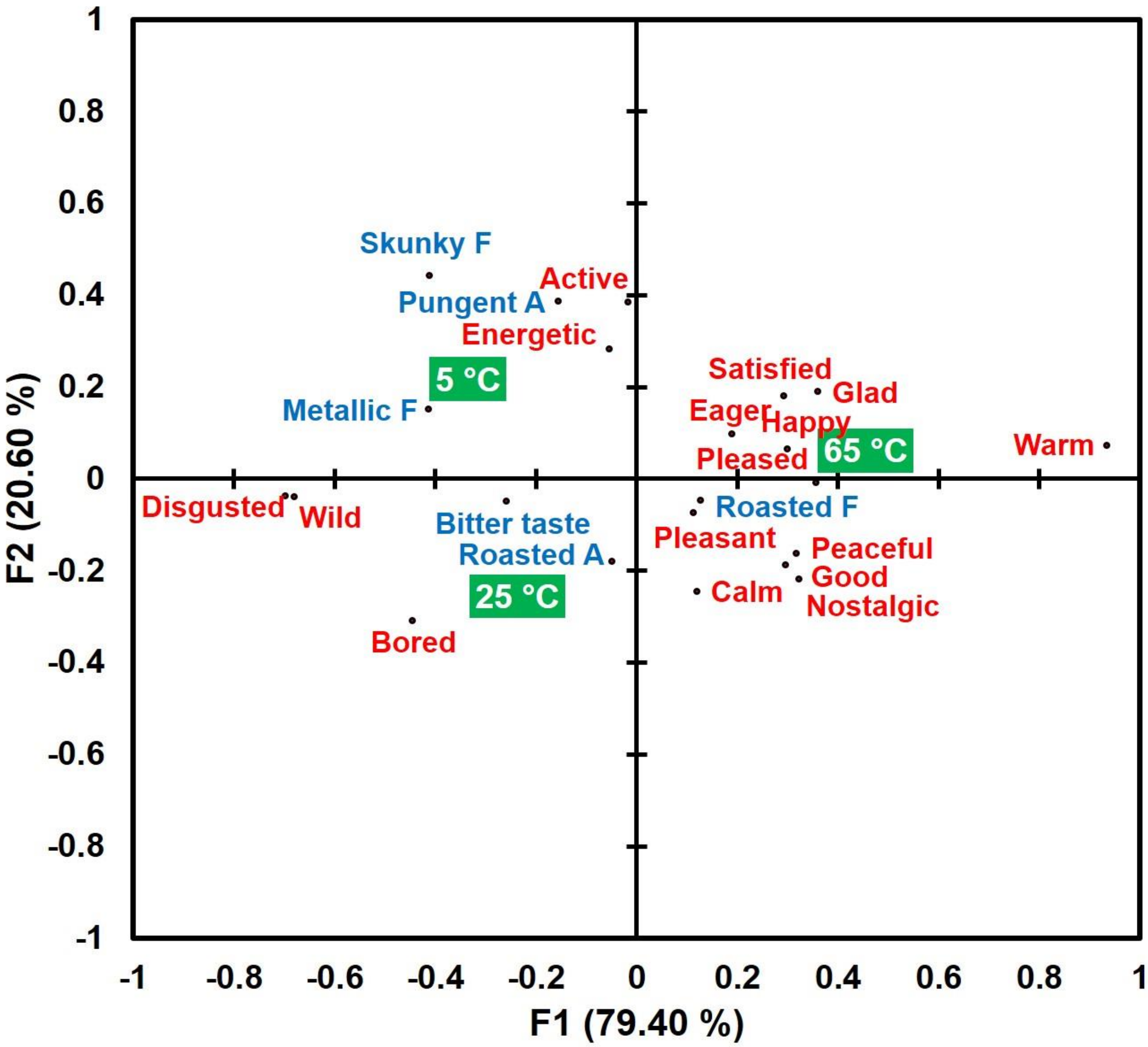
Figure 4. A bi-plot drawn by the correspondence analysis in the associations of sample temperatures with emotional responses (red) and sensory attributes (blue) in green tea samples evaluated at the three temperatures (green squares). "A", "F", "M", and "AT"

next to sensory attribute term represent “aroma”, “flavor”, “mouthfeel”, and “aftertaste”, respectively.

Figure 5. Mean drops in overall liking with respect to emotional responses and sensory attributes in green tea samples as a function of sample temperature: all temperatures (A), 65 °C (B), 25 °C (C), and 5 °C (D). “A”, “F”, “M”, and “AT” next to sensory attribute term represent “aroma”, “flavor”, “mouthfeel”, and “aftertaste”, respectively. Numerical value of each emotion or sensory attribute term represents a mean difference in overall liking between the selected and unselected cases; a positive (or negative) value for each term indicates an increase (or decrease) of overall liking between the selected and unselected cases.

Figure 6. Mean drops in overall liking with respect to emotional responses and sensory attributes in green tea samples as a function of gender: females (A) and males (B). “F”, “M”, and “AT” next to sensory attribute term represent “flavor”, “mouthfeel”, and “aftertaste”, respectively. Numerical value of each emotion or sensory attribute term represents a mean difference in overall liking between the selected and unselected cases; a positive (or negative) value for each term indicates an increase (or decrease) of overall liking between the selected and unselected cases.

Figure 1.



Skunky F
Active
Pungent A
Energetic
5 °C
Metallic F
Satisfied
Glad
Eager
Happy
65 °C
Warm
Pleased
Disgusted
Wild
Bitter taste
Roasted A
25 °C
Bored
Roasted F
Pleasant
Peaceful
Good
Calm
Nostalgic
F2 (20.60 %)
F1 (79.40 %)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

Figure 2.

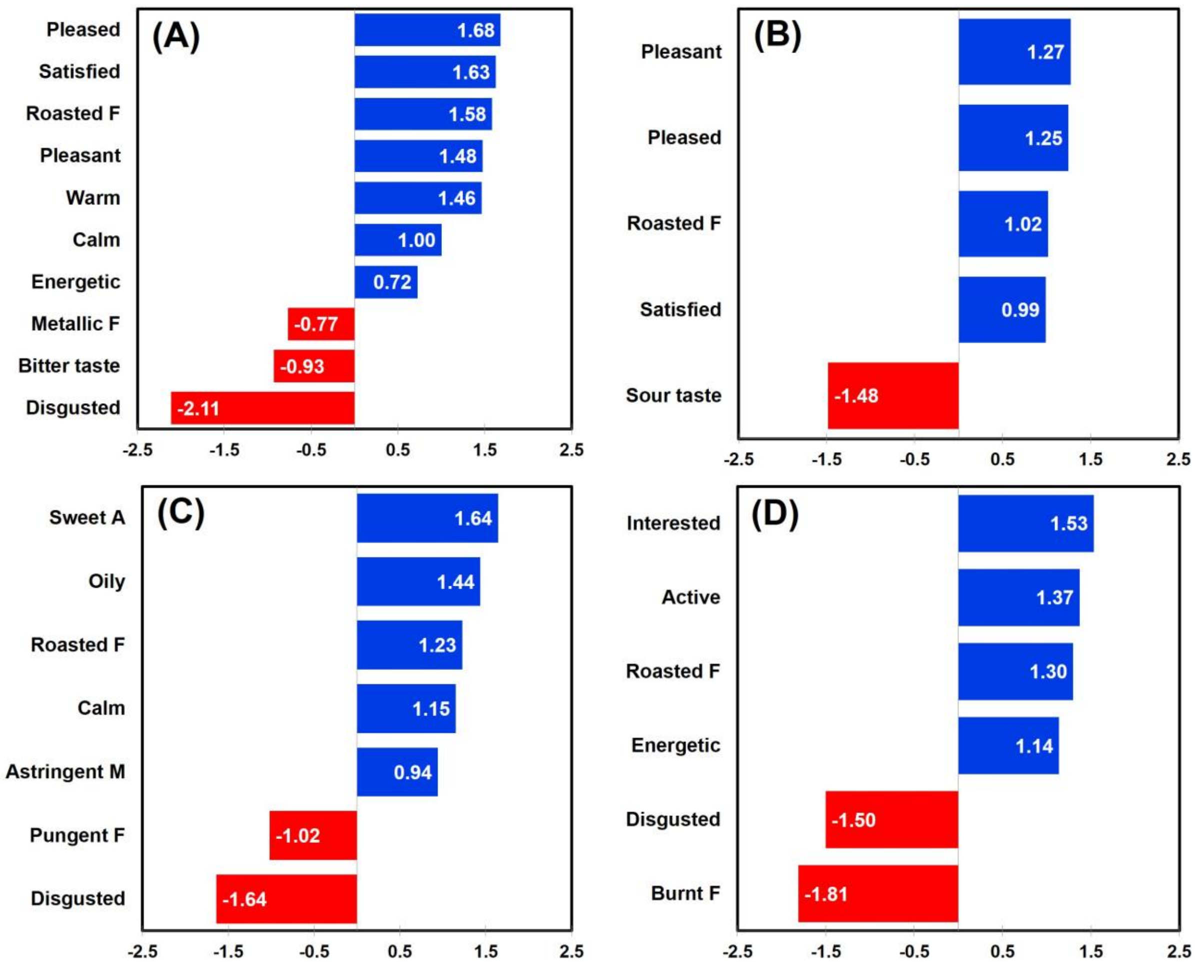

(A)
Pleased
Satisfied
Roasted F
Pleasant
Warm
Calm
Energetic
Metallic F
Bitter taste
Disgusted
1.68
1.63
1.58
1.48
1.46
1.00
0.72
-0.77
-0.93
-2.11
(B)
Pleasant
Pleased
Roasted F
Satisfied
Sour taste
1.27
1.25
1.02
0.99
-1.48
(C)
Sweet A
Oily
Roasted F
Calm
Astringent M
Pungent F
Disgusted
1.64
1.44
1.23
1.15
0.94
-1.02
-1.64
(D)
Interested
Active
Roasted F
Energetic
Disgusted
Burnt F
1.53
1.37
1.30
1.14
-1.50
-1.81
-2.5
-1.5
-0.5
0.5
1.5
2.5

Figure 3.

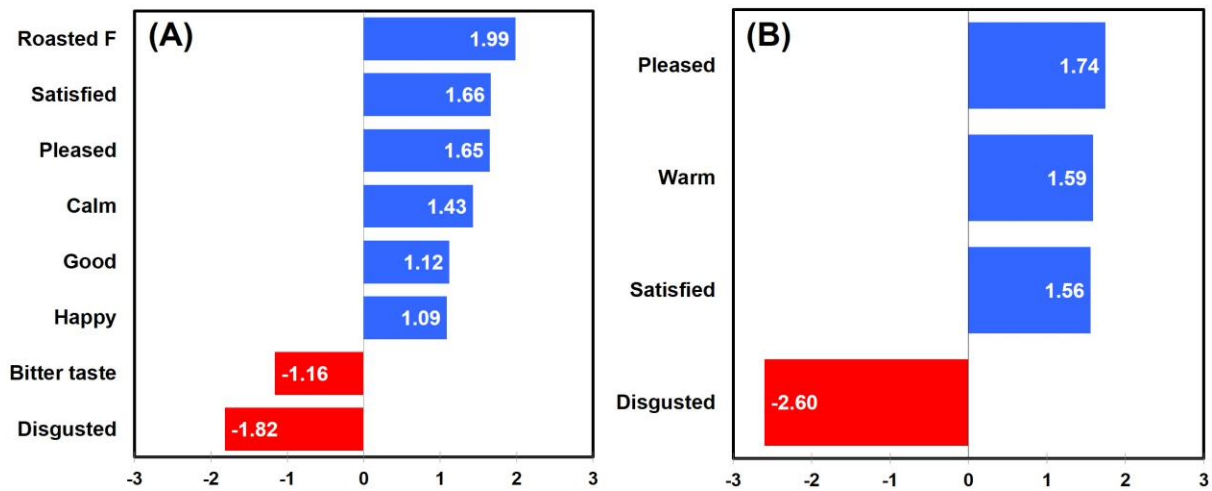
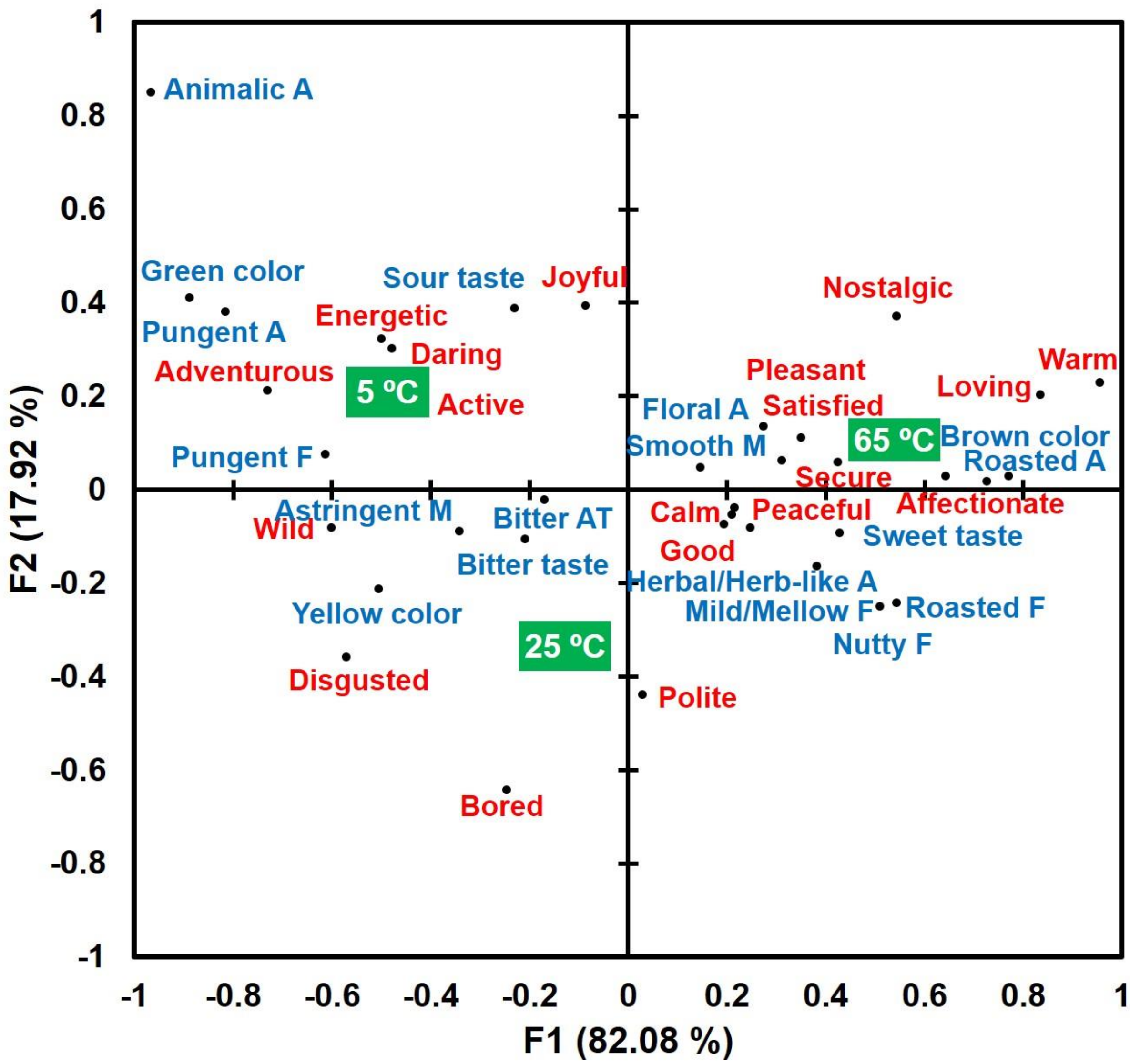
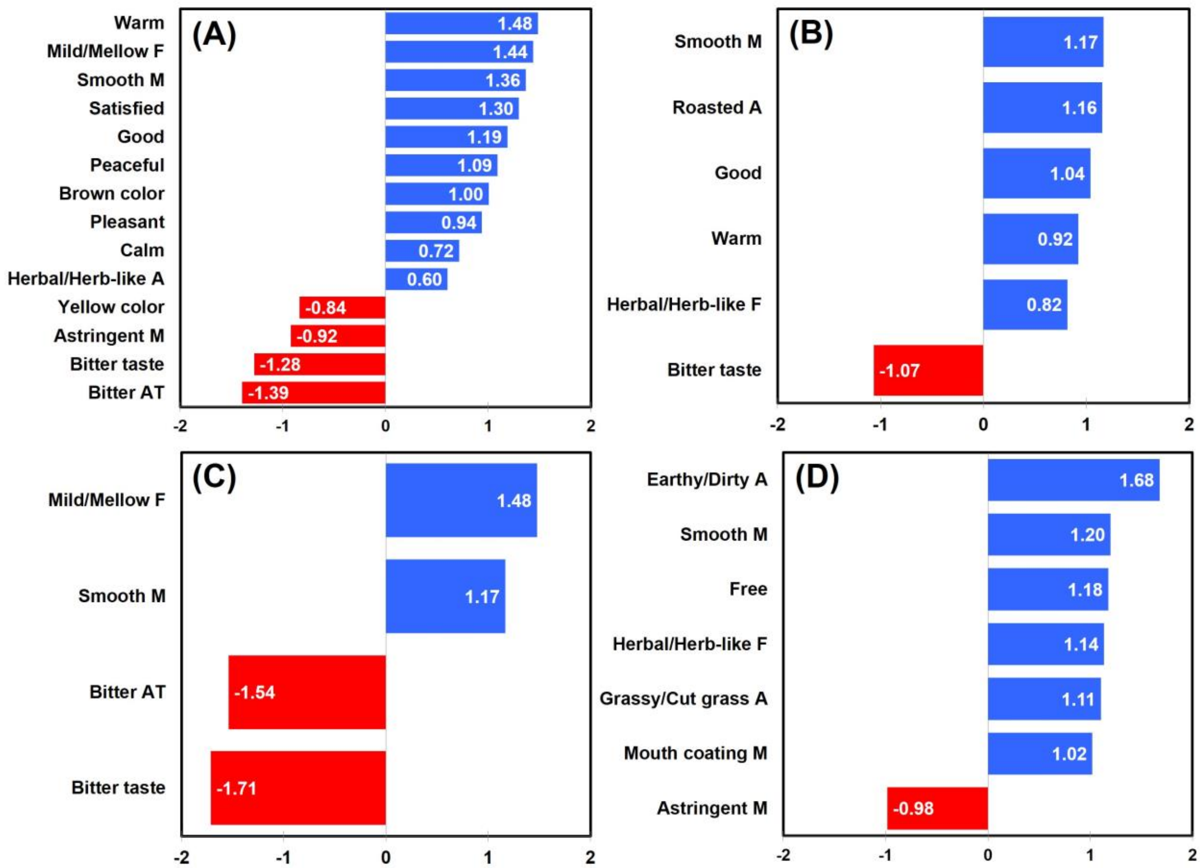

(A)
Roasted F
Satisfied
Pleased
Calm
Good
Happy
Bitter taste
Disgusted
1.99
1.66
1.65
1.43
1.12
1.09
-1.16
-1.82
-3
-2
-1
0
1
2
3
(B)
Pleased
Warm
Satisfied
Disgusted
1.74
1.59
1.56
-2.60
-3
-2
-1
0
1
2
3

Figure 4.



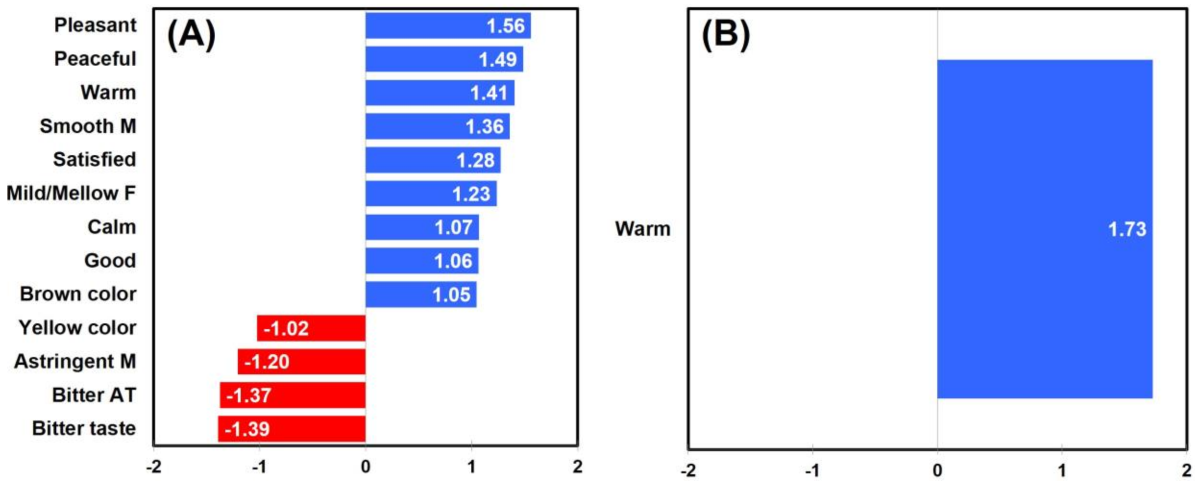
Animalic A
Green color
Pungent A
Adventurous
Pungent F
Sour taste
Joyful
Energetic
Daring
5 ºC
Active
Nostalgic
Pleasant
Warm
Loving
Floral A
Satisfied
Smooth M
65 ºC
Brown color
Roasted A
Secure
Affectionate
Calm
Peaceful
Sweet taste
Good
Herbal/Herb-like A
Mild/Mellow F
Roasted F
Nutty F
Astringent M
Wild
Bitter AT
Bitter taste
Yellow color
25 ºC
Disgusted
Polite
Bored
F1 (82.08 %)
F2 (17.92 %)

Figure 5.



(A)
Warm
Mild/Mellow F
Smooth M
Satisfied
Good
Peaceful
Brown color
Pleasant
Calm
Herbal/Herb-like A
Yellow color
Astringent M
Bitter taste
Bitter AT
1.48
1.44
1.36
1.30
1.19
1.09
1.00
0.94
0.72
0.60
-0.84
-0.92
-1.28
-1.39
(B)
Smooth M
Roasted A
Good
Warm
Herbal/Herb-like F
Bitter taste
1.17
1.16
1.04
0.92
0.82
-1.07
(C)
Mild/Mellow F
Smooth M
Bitter AT
Bitter taste
1.48
1.17
-1.54
-1.71
(D)
Earthy/Dirty A
Smooth M
Free
Herbal/Herb-like F
Grassy/Cut grass A
Mouth coating M
Astringent M
1.68
1.20
1.18
1.14
1.11
1.02
-0.98
-2
-1
0
1
2

Figure 6.


(A)
Pleasant
Peaceful
Warm
Smooth M
Satisfied
Mild/Mellow F
Calm
Good
Brown color
Yellow color
Astringent M
Bitter AT
Bitter taste
1.56
1.49
1.41
1.36
1.28
1.23
1.07
1.06
1.05
-1.02
-1.20
-1.37
-1.39
-2
-1
0
1
2
(B)
Warm
1.73
-2
-1
0
1
2

CHAPTER 4. Cross-modal association between hand-feel touch factor and taste cues

Abstract

Cross-modal associations across sensory modalities have frequently been reported. Among the 5 senses, hand-feel touch has received the least attention with respect to its influence on product evaluation in food and beverages. Touch is closely associated with emotions and other senses because of its primitive function of communicating emotional intent to others. Due to such intimacy between emotions and product acceptability, the effects of hand-feel touch on both emotional responses and sensory perception should be investigated. Because coffee is popularly consumed worldwide, this study aimed to capture cross-modal associations between hand-feel touch from different cup sleeves, and basic tastes imagined (Study 1) or tasted (Study 2) within the context of coffee drinking experience, with instrumental analyses performed using 3D Laser Microscope and Universal Testing Machine to quantify textural characteristics of cup sleeves. A total of 170 participants (105 females) aged 19 to 72 evaluated 12 cup sleeves in terms of emotional responses evoked, using descriptive terms related to coffee drinking experience with a Check-All-That-Apply (CATA) procedure, and the degree of matching on 9-point scales to 4 basic tastes (bitter, sweet, sour, salty) and coffee-related flavors. Results demonstrated cross-modal associations between hand-feel touch and basic taste cues. Specific associations were: bitter taste and black coffee flavor with cardboard sleeves; sweet taste and creamy flavor with towel; sour taste with silicone (Study 1) and stainless steel (Study 2); salty taste with linen (Study 2). Correlational analyses reflected relationships between certain textural parameters and sensory cross-modal associations. Specifically, thicker and rougher materials positively correlated with positive emotional terms and sweet taste, while thinner and smoother materials positively correlated with negative and high-energy emotional terms and sour taste. This study showed that hand-feel touch cues could indeed influence cognitive associations with basic tastes and coffee-related flavors. Furthermore, this study revealed that context effects and familiarity effects were dominant over hedonic matching in the context of cross-modal association between hand-feel touch and taste cues. The study demonstrated that touch plays a

crucial role in product evaluation, suggesting that food and beverage professionals could attempt to incorporate more hand-feel textural features in packaging or container designs.

Keywords: touch, cross modal, emotional response, sensory attribute, coffee, sleeve materials

1. Introduction

Consumer preference and purchase decision toward food and beverages are influenced by both intrinsic (i.e., product-specific) and extrinsic (i.e., non-product-specific) characteristics (Köster, 2009). While puchasing food or beverage products in the market, sensory cues, such as appearance and odor, may add consumer expectation about both product performance and sensory perception during consumption (Grunert et al., 1996). Sensory information from which consumers may tend to build expectations includes sensory cues experienced when handling a product during consumption (Lefebvre et al., 2010), such as touching the packaging while opening a product or holding the packaging while consuming a product. Previous research has also demonstrated that, in rating product attributes, consumers generally seemed to mimic their rating of container attributes with respect to physical attributes such as “softness” or “fragility” (Schifferstein, 2009). In addition, in the same study, more abstract terms such as “independent” or “interesting” used to describe the experience of drinking a real beverage sample, were also used in describing the empty cup itself. Another study demonstrated by Piqueras-Fiszman and Spence (2012) found that panelists awarded higher crunchy and hardness ratings for biscuits presented in pots with rough outside texture, while yogurt presented in pots with smooth texture received higher smoothness ratings. Such results reflect the obvious conclusion that, in addition to the intrinsic sensory characteristics of a product, consumer experience related to product packaging or container characteristics can also influence consumer sensory perception of the product.

While hand-feel touch cues have been extensively studied in the field of textile and apparel design (Winakor et al., 1980; Alimaa et al., 2000; Cardello et al., 2003; Philippe et al., 2004; Grohmann et al., 2007, Jeguirim et al., 2010; Liao et al., 2016), the rise of increased consumer demand for more immersive sensory experience, has resulted in more progressive touch or haptic cues being applied with food and beverage products. One way to incorporate the experience of using sense of touch is to alter the packaging and/or container design associated with product consumption. Since current technological developments support cheaper and faster development of innovative extrinsic product design, manufacturers should adapt such concepts when developing new products or even when updating existing product characteristics (Spence & Gallace, 2011). A study conducted by Grohmann et al. (2007) found that, for products with attributes lending themselves to touch exploration, tactile inputs impart positive effects on product evaluation. That study also found that consumer product evaluation depends on product quality, with products deemed to be of high quality evaluated more positively when touched and products of lower quality rated more negatively when touched. Spence and Gallace (2011) have suggested that the findings of their study may reveal that for certain items (e.g., textiles or cell phones), tactile product quality should be prioritized above visual quality with respect to product development.

Previous research has revealed cross-modal associations between hand-feel touch and other sensory modalities, possibly related to sensation transference (Schifferstein, 2009). Such cross-modal phenomenon is an ingrained process whereby people intuitively connect inputs from different sensory modalities (Becker et al., 2011; Spence, 2011). The generally assumed explanation that underlies this phenomenon is that, since packaging and content are presented in rapid succession in everyday life, people may derive meaningful information or connotations from the packaging’s presented sensory cues of the packaging, thereby setting up expectations toward the content (Garber et al., 2001; Becker et al., 2011). Earlier studies showing that flavor perception of food and beverages can be affected by packaging shape (Deroy and Valentin, 2011; Slocombe et al., 2016; Cavazzana et al., 2017; Mirabito et al., 2017; van Rompay et al., 2017), weight (Piqueras-Fiszman et al., 2011; Kampfer et al., 2017), materials (Tu et al., 2015), and roughness (Biggs et al., 2016) allowed participants to explore the packaging haptically using their hands. In the case of cross-modal association of product flavors with packaging or container shapes, it has been generally accepted that rounder packaging shapes are more associated with sweeter products (Deroy and Valentin, 2011) and those with less intense in sweetness (Becker et al., 2011). Biggs et al. (2016) also found that biscuits presented on rough plates were rated less sweet than those presented on smooth plates.

Although previous studies have examined the consequences of container or packaging design characteristics on sensory perception, there are still relatively few studies involving associations of hand-feel touch cues with other sensory modalities, an emerging focus in the food and beverages field. Moreover, a majority of such studies have focused on packaging shape, leaving many other textural variables for further research. In particular, hand-feel touch cues in the form of materials variation would be of great value because of increasing public interest in reusable materials and products with novelty value. The market exhibits increased variety in cup sleeves or tumbler materials used in consumption of cold or hot beverages such as coffee. Previous research has shown that touch cues are closely related to human emotional responses, and in interpersonal interactions, touch can stimulate either positive or negative emotional responses (Knapp & Hall, 1997; Hertenstein & Keltner, 2006). In fact, Desmet (2010) proposed that the emotional influence of a product on an individual is dependent on "*its material qualities, purposes, meanings, expressions, and on what it does or fails to do*". To assess material quality, purpose, and success of a product design, individuals must obviously physically touch the product. In the field of product design, physical features of a product, such as its weight, texture, and surface, comprise its tangibility and can considerably influence consumer appreciation of its value (Ortony et al., 1988). Touching a product can also contribute to the complete experience of human-product interaction in which an individual is able to touch, feel, and receive affective pleasure from a tangible object. Touch-emotion interaction has been reported to manifest itself in a form of synaesthesia where *"nearly all tactile textures (e.g., velvet or wax) consistently and reliably evoke highly specific, and strong emotions"* (Ramachandran & Brang, 2008). In the case of the two individuals discussed in the aforementioned report, since touching leather evoked in one individual a feeling of being embarassed and criticized, while touching fleece evoked a feeling of digust in the other. It would present an interesting dimension to investigate whether hand-feel touch cues can elicit different emotional responses or whether such touch cues could be specifically associated with particular emotions.

Considering the popularity of coffee beverages in the United States market, it is important to study cross-modal associations of extrinsic hand-feel haptic cues in the form of varying cup sleeve materials, with basic tastes, as well as the effects of such cues on emotional responses. This study aimed to determine whether hand-feel touch cues of sleeve materials could elicit specific emotional responses and whether certain of those cues could be more associated with specific basic tastes and coffee-related flavors. This study was composed of three studies. Study 1 was designed to determine influences of hand-feel touch cues on emotional responses and matching associations with “imagined” basic tastes. Because individual differences in perception are well known, by simply capturing consumer responses with verbal descriptors of the basic tastes on ballots, it is possible that a sensation deemed to be, e.g. “bitter”, by one person could be perceived as something other than “bitter” by another person. As an example, Ishii and O'Mahony (1990) found that when presented with different sets of standards, participants generated various definitions of umami. For this reason, Study 2 was initiated to determine the influences of hand-feel touch cues on matching associations with basic tastes “consumed”. To evaluate relationships between sensory cross-modal association data and instrumental data measuring physical attributes of the various cup sleeve materials, instrumental measurements of those materials were included in both Studies 1 and 2. As emphasized by Szczesniak (1986), data using instrumental procedures could provide a better understanding and explanation of sensory trends and observations generated in sensory studies. Since previous studies on cross-modal correspondence between hand-feel touch and taste cues have provided only plausible theories based on previous literature, rather than providing empirical evidence, instrument-based measurements were included in hope of determining whether correlation existed between sensory cross-modal association data and instrument-based physical attribute measurements.

This study was conducted according to the Declaration of Helsinki for studies on human subjects. The protocol used in this study was approved by the Institutional Review Board of the University of Arkansas (Fayetteville, AR, USA). A written informed consent was obtained from each participant prior to participation.

2. Study 1: Influences of hand-feel touch cues on matching associations to imagined basic tastes

2.1. Materials and methods

2.1.1. Participants

One hundred and two participants (69 females and 33 males) of ages ranging from 19 to 72 years [mean age ± standard deviation (SD) = 37 ± 15 years] were recruited using the consumer profile database of the University of Arkansas Sensory Service Center (Fayetteville, AR, USA). Participants self-reported no diseases or conditions that would affect their taste or hand-feel sensitivities. Participants also self-reported habitual consumption of at least one cup of coffee beverage per day.

To ensure that participants possess acceptable hand-feel stereognostic ability to distinguish between different sleeve textures (see below), they were asked to identify a set of 8 wooden letters (Hobby Lobby, Oklahoma City, OK, USA). The procedure closely followed the “letters test” used by Luckett et al. (2016) with several modifications. To elaborate, the modifications included using wooden alphabetical letters: A, I, J, L, O, T, U, and W (Essick et al., 1999) instead of confectionary letters. Another modification was that instead of asking participants to explore using their tongue intraorally, participants were asked to identify each letter placed on their non-dominant hand by freely exploring using their fingers of dominant hand. The letters were presented using a monadic sequential design. Their tactual stereognosis score were calculated as the number of correct answers out of 8. Qualified participants scored at least 6 out of 8.

2.1.2. Samples and preparation

As described above, touch cues were presented as a form of cup sleeve. To minimize potential effects of size and shape of cup sleeves, the cup-sleeve samples used in this study were designed such that common cardboard cup-sleeves were covered fully with each eleven different materials, except for a cardboard sleeve with no additional coverage. The twelve sleeve-materials were selected to best represent the cup sleeve materials that are currently available in the market, as well as those that represent a wide variety of hand-feel touch cues. Twelve cup-sleeve samples of varying materials were used in this study can be shown in **Table 1**.

2.1.3. Check-All-That-Apply (CATA) questions for measuring emotional responses

To quickly capture the emotional responses evoked by hand-feel touch cues in the form of the different cup-sleeve materials, a Check-All-That-Apply (CATA) question was used. The CATA question included 44 emotion terms from a product-specific Coffee Drinking Experience (CDE) scale developed by Kanjanakorn and Lee (2016) based on a lexicon established by Bhumiratana et al. (2014). The CATA method involves the participants to select all the terms they consider could best describe the evoked emotions from the different materials. This method has been considered to be easy to understand by naïve consumer participants, highly reproducible, and could yield high discriminative ability among different samples as used by naïve participants (Ares et al., 2010; Bruzzone et al., 2012; Jaeger et al., 2013; Cadena et al., 2014).

2.1.4. Procedure

Participants were given orientation for the study procedure and ballot prior to the study. Participants were then seated at individual sensory booths, and presented with a modified cardboard box containing an empty 12-oz. paper cup with the different sleeves fitted on. As shown in **Figure 1**, the box was modified such that the participants were able to put both their hands into the box and feel for the sleeves using their hands. After touching each sleeve material by both hands for 15 s, participants were asked to answer the questions regarding their evoked emotions, familiarity of the hand-feel of the sleeve, and matching of the sleeve material to basic tastes/flavor. As described earlier, emotional responses evoked by sleeve samples were measured using the emotion CATA question. Familiarity ratings were done on 9-point scales ranging from 1 (“extremely unfamiliar”) to 9 (“extremely familiar”), while matching questions (“*How well does the texture or hand-feel of this cup sleeve match …?*”) to four basic tastes (bitter, salty, sour, and sweet tastes), creamy flavor, and black coffee flavor were answered on 9-point scales ranging from 1 (“extremely unmatched”) to 9 (“extremely matched”).

In between samples, participants were asked to read a part of an emotionally-neutral news article (11 news articles published at BBC website, http://www.bbc.com, from June 5th to August 18th, 2017; e.g., http://www.bbc.com/news/science-environment-41002562) to help neutralize the participants’ emotions back to their baseline prior to the evaluation of the next sample and reduce emotional carry-over effect from previous samples. Distraction tasks or task-irrelevant distractors have also been shown to improve participant performance (Olivers and Nieuwenhuis, 2005; Sussman et al., 2013).

2.1.5. Instrumental texture measurements

Instrumental texture measurements were conducted using two separate instruments: 3D Laser Scanning Confocal Microscope (Model VK-X260K, Keyence Corporation, Chicago, IL, USA) and Universal Testing Machine (UMT-2, Bruker Nano Surfaces, San Jose, CA, USA). 3D Microscope allowed researchers to measure physical surface texture characteristics of the cup sleeves, such as arithmetical mean height (Sa), maximum surface height (Sz), surface uniformity (Str), mean peak curvature (Spc), surface slopeness via developed interfacial area ratio (Sdr), and standard deviation of surface height (Sq). For definitions of the parameters measured, refer to **Table 2**. The 3D Microscope measurements were conducted at 10x magnification in triplicate, with mean values reported. Data analyses for 3D Microscope evaluation employed the following specific parameters used for data filtering: surface shape correction (tilting/waveform removal), smoothing, medium height cut level, and reference plane setting. Using the Universal Testing Machine (UTM), two tests were carried out: (a) identification of the deformation of sleeve materials using 0.5 N constant load for 10 secs (static condition) and (b) evaluation of the coefficient of friction (COF) of sleeve materials at 0.5-1.2 N load (gradually increased load). The travel distance during the COF measurement was 1.2 mm at the speed of 0.1 mm/s. In both (a) and (b) cases, silicone pin (6.35 mm diameter) was used as counter-face materials. COF was measured under gradually increased load to account for the variability in the grip strength of individuals. As a reference, Kargov et al. (2004) established that the average grip force of a human hand was 0.8 N.

2.1.6. Statistical analysis

Data were analyzed using XLSTAT statistical software (Addinsoft, New York, NY, USA) and JMP Pro (version 13, SAS Institute, Cary, NC, USA). Cochran's Q test (Cochran, 1950) was performed to determine whether the proportions of selection by participants for individual emotion terms differed by sleeve samples. If significant differences were found, post hoc multiple pairwise comparisons were performed using McNemar's test with Bonferroni alpha adjustment. Correspondence analysis, based on chi-square distance, was used to visualize relationships of sleeve samples with emotional responses. Significant terms of the emotion CATA questions, as determined by the Cochran's Q-test, were used for correspondence analysis. Principal component analysis (PCA) was performed on the standardized mean values of responses to basic taste matching questions to illustrate correlations between sleeve samples and the basic tastes. A two-way analysis of variance (ANOVA), treating “sleeve sample” and “panelist” as fixed and random effects, respectively, was conducted to whether sleeve samples could differ with respect to familiarity to the hand-feel of the sleeve materials and degree of matching to basic tastes, black coffee flavor, and creamy flavor. Where a significant difference was present, multiple pairwise comparisons using Tukey’s honest significant difference (HSD) were performed. A statistically significant difference was defined to exist when $P < 0.05$.

A one-way analysis of variance (ANOVA) was performed to determine whether the sleeve materials could differ with respect to the texture parameters measured instrumentally using the 3D Laser Scanning Confocal Microscope, i.e., Sa, Sz, Str, Spc, Sdr, and Sq. Pearson correlation analysis was conducted to examine relationships between the proportions of selections of emotional terms obtained using the CATA procedure and instrumental data obtained.

2.2. Results

Chi-square test of independence revealed that the proportions of selections by participants for all emotion terms were significantly different among the different cup sleeve materials ($\chi^2 = 968.00$, $P < 0.001$). More specifically, Cochran’s Q-test showed that 33 of the CDE emotion terms elicited significantly differed as a function of cup sleeve materials: “active”, “annoyed”, “awake”, “balanced”, “bored”, “comfortable”, “content”, “curious”, “disappointed”, “disgusted”, “empowering”, “energetic”, “fulfilling”, “fun”, “good”, “in control”, “joyful”, “jump start”, “merry”, “nervous”, “off-balance”, “peaceful”, “pleasant”, “pleased”, “relaxed”, “rested”, “rewarded”, “satisfied”, “soothing”, “special”, “understanding”, “warm”, and “worried”.

A bi-plot of correspondence analysis visualizes the associations between the 33 emotion terms and cup sleeve materials (**Figure 2**). As the bi-plot is based on chi-square distance, sleeve materials positioned close together on the bi-plot could be interpreted as eliciting the same emotional terms. In this manner, silicone, stainless steel, rayon, and leather sleeves were more associated with “annoyed”, “curious”, “disgusted”, “empowering”, “energetic”, “fun”, “grouchy”, and “worried”. Suede, felt, and terry sleeves were more associated with “fulfilling”, “joyful”, “merry”, “pleased”, “rested”, “rewarded”, “soothing”, and “special”. Nylon, polyester, and linen were more associated with “active”, “awake”, “disappointed”, “jump start”, “nervous”, and “off balance”. Cotton was more associated with “satisfied”, “pleasant”, “comfortable”, “peaceful”, and “content”, while cardboard was more associated with “bored” and “understanding”.

With regards to comparisons of the degree of matching associations to the four basic tastes (bitter, sweet, sour, salty) and familiarity to the hand-feel of the cup sleeve materials, ANOVA results revealed that for all the four basic tastes and coffee-related flavors, there were significant main effects of cup sleeve materials [$F(11,101) = 6.58$, $P < 0.001$], except for salty taste (**Table 3**). More specifically, post hoc multiple pairwise comparisons showed that cardboard sleeves were deemed to match bitter taste the most and black coffee flavor, and were also the most familiar in terms of hand-feel textural attributes. In fact, cardboard sleeves were significantly more matched with black coffee flavor than with any other materials ($P < 0.05$). Towel sleeves were regarded to match sweet taste the most and creamy flavor, and were considered to be the second most familiar in terms of hand-feel. Sour taste was most matched with silicone sleeves. Although there was no significant main effect of cup sleeve materials for matching association to salty taste, linen sleeve was considered to match the most with this taste quality. Supporting the ANOVA results, PCA bi-plots, which illustrated the relationships between the different sleeve materials and imagined basic tastes, showed that sweet taste was most associated with towel, sour taste with silicone, and salty with linen (**Figure 3**). Furthermore, the bi-plots showed that 87.41% of the total variation in the data varied with respect to the varying hand-feel cues in the form of different cup sleeve materials.

The 3D Microscope instrument allowed for the analyses of 6 surface texture parameters on the varying cup sleeves: Sa (arithmetical mean height), Sz (maximum height), Str (texture aspect ratio), Spc (arithmetic mean peak curvature), Sdr (developed interfacial area ratio), and Sq (root mean square height). It was found that the cup sleeves significantly differed in 5 parameters: Sa [$F(11,24) = 53.8$, $P < 0.001$], Sz [$F(11,24) = 24.4$, $P < 0.001$], Spc [$F(11,24) = 23.9$, $P < 0.001$], Sdr [$F(11,24) = 40.3$, $P < 0.001$], and Sq [$F(11,24) = 56.1$, $P < 0.001$] (**Table 4**). Generally, fabric-based cup sleeves appeared to have higher Sa, Sz, Spc, Sdr, and Sq values, which agreed with visual inspection of surface texture properties and common assumption that these materials would exhibit softer, more pleasant physical attributes. In contrast, stainless steel consistently possessed the lowest values for Sa, Sz, Spc, Sdr, and Sq. Wool was observed to possess the highest Sa value with mean (± SD) rating of 45.1 (± 4.84), while stainless steel had the lowest with mean (± SD) rating of 0.454 (± 0.014), indicating that wool maintained the highest average of the absolute values of the extremes of the surface and therefore, had the highest surface roughness. It must be noted that Okamoto et al. (2013) established five potential dimensions of tactile perception: macro and fine roughness, warmness/coldness, hardness/softness, and friction (moistness/dryness, stickiness/slipperiness). In addition, surface roughness, as a textural attribute, comprises of numerous parameters (Mooneghi et al., 2014). Thus, Sa measured one aspect of roughness, while coefficient of friction, evaluated using UTM, measured another. Wool also generated the highest Sz value with 304 (± 82.3), signifying that it had the highest thickness compared to the other cup sleeve materials. In terms of the roundness of the tips of the raised surfaces (Spc), towel was observed to have the highest with wool being the second highest with values of 3951 (± 806) and 2632 (± 793), respectively. This indicated that the peaks of the surface in towel and wool tended to be less round. Sdr represents the steepness of the slopes of the surface peaks. Again, wool and towel showed the 2 highest values of 11.4 (± 3.08) and 10.4 (± 1.42), respectively, while stainless steel had the lowest at 0.0428 (± 0.000894), which suggested that wool and towel had more raised, steeper surfaces, contrary to the smooth, level surface of stainless steel. Finally, Sq values predictably followed the trend observed for Sa values, as Sq measured the standard deviation of the surface peaks.

The UTM tool allowed for the measurements of surface deformation and friction for the 12 different cup sleeves. **Figure 4** illustrates the changes in deformation of the varying cup sleeves over a period of 10.1s under compression load of 0.5N. Higher deformation values imply that the material would be more compressed and deformed under the specified load. Here, towel was consistently highest in deformation values, whereas stainless steel was consistently lowest. The results agreed with the comparison between maximum deformation values of the varying cup sleeves (**Figure 5**). Additionally, friction data showed that stainless steel was consistently lowest in terms of coefficient of friction values under compression load of 0.5-1.2 N, while leather was consistently highest. Generally, fabric-based materials were positioned in the middle of the chart. Again, these results agreed with the mean coefficient of friction values of the varying cup sleeve materials.

Correlation analysis showed some significant correlations between instrumental data measurements evaluated using 3D Microscope and UTM, and the proportions of selections of the Coffee Drinking Experience (CDE) emotional terms obtained through the CATA procedure (**Table 5**). Overall, Sa, Sz, Spc, Sdr, and Sq exhibited similar correlational trends, whereby these five parameters positively correlated with the following emotional attributes: “comfortable”, “content”, “fulfilling”, “good”, “joyful”, “merry” (Sz, Spc, Sdr, and Sq only), “peaceful”, “pleasant” (Sz, Spc, and Sdr only), “pleased”, “relaxed”, “rested”, “satisfied”, “soothing”, “special” (Spc and Sdr only), and “warm”. These five parameters negatively correlated with the following emotional attributes: “active”, “annoyed”, “disappointed”, “jolted” (Sa, Sz, Spc, and Sq only), and “social”. While maximum deformation did not significantly correlate with any of the emotional attributes, coefficient of friction positively correlated with “balanced” and “satisfied”, and negatively correlated with “active”, “energetic”, and “grouchy”. Thus, these correlational relationships suggested that overall, higher Sz, Spc, Sdr, Sq, and maximum deformation values tended to be more associated with positive emotional terms and less associated with negative and high-energy terms.

2.3. Discussion

The present study presented a novel element to the sensory studies investigating the influences of hand-feel touch cues because it illustrated the impacts of different hand-feel touch inputs and highlighted how these cues elicited different emotional responses, as well as cognitive associations with certain tastes and flavors related to coffee beverages. The results from this study revealed that different cup sleeve materials could elicit diverse emotional profiles, which supported the well-known association between touch and emotions in previous literatures. Historically, touch has been known to be a means of meaningful communication between an individual and their surroundings, including other individuals and objects nearby. Specific to human behavior, hand-feel touch exploration has been observed in young children as it is considered to be the most developed sensory modality at birth, and assists in the development of cognitive, brain, and socioemotional aspects of an individual throughout childhood (Field, 2001; Stack, 2001; Hertenstein, 2002; Hertenstein & Keltner, 2006). As such, humans possess the tendency to relate hand-feel touch inputs with affective or emotion-related communication. In fact, in a functional magnetic resonance imaging (fMRI) study conducted by Rolls et al. (2003), the researchers discovered that when individuals were subjected to affectively positive or pleasant (in the form of Suede fabric), and negative or painful hand-feel touch stimuli, there was a higher activation in the somatosensory cortex compared to neutral touch stimuli. Specifically, the orbitofrontal cortex were observed to be involved in affective inputs from touch stimuli, in addition to inputs from other sensory modalities, such as odor, and reward (Rolls, 2000). This close connection between touch and emotion-related communication from an object was reflected in results of the present study, which indicated that 75% of the emotional CATA terms were significantly different as a function of cup sleeve materials. As the the cup sleeve materials evaluated were applied to specifically coffee-drinking experience, the emotional terms used in the present study reflected emotions that could be elicited in such an experience, which contributed to the novelty of the present study. In previous literatures, various textiles were often described using emotional terms of related to the quality of clothing items, e.g., luxurious, comforting, sensual (Moody et al., 2001), elegant, or fashionable (Orzechowski, 2016). As expected, people often describe items in accordance to the functions of the finished products, although these did not apply to experts, whose rating of appropriateness of fabrics were not affected by end-use context (Dacremont & Soufflet, 2006). Since fabrics have been historically utilized as materials for fashion items such as shirts and scarves, it would be commonplace for individuals to associate and apply emotional terms of such items to descriptions of textiles. Therefore, when drawing inferences from this study, it must be noted that the participants evaluated the hand-feel attributes of these materials in the context of coffee drinking.

In the present study, cardboard was rated to display the most familiar hand-feel attributes than the rest of the materials. Due to regular encounter of cardboard cup sleeves in daily life, especially in coffee drinking situations, it was expected that they would rate such material with emotional terms such as “bored” and “understanding”. In contrast, participants considered stiffer sleeves, such as silicone, stainless steel, and leather, to be more associated with emotional terms embodying curiosity (“curious”, “fun”, “worried”), possibly due to the lower familiarity ratings of the hand-feel of these sleeve materials. The lower familiarity ratings for these sleeve materials could also provide some reasoning to the negative affective terms used (“annoyed”, “disgusted”, and “grouchy”). Products that exhibit novel characteristics could motivate individuals to explore their quality through hand-feel touch exploration (Mooy & Robben, 2002), resulting in the elicitation of emotional terms related to curiosity. However, it was probable that because the participants were not allowed to visually evaluate the cup sleeve materials during the evaluation, they were unable to confirm their original product assessment from hand-feel exploration, resulting in negative emotional terms related to frustration (“annoyed” and “grouchy”). The findings of Macaluso et al. (2000) illustrated the close linkage between touch and visual cues, where they discovered through an fMRI study that touch cues projected to the somatosensory cortex could influence the visual cortex through connective areas in the parietal lobe. One positive emotional term used to describe this group of sleeve materials, “empowering”, could reflect the sensory characteristics of the materials. Because the materials were less malleable and more stiff, it was possible that the participants selected the term “empowering” to describe the emotional connection to that sensory quality. In addition, leather has also exhibited the same association to “fear”, “anger”, “surprise”, “passionate”, “impulsive”, and “strength” in previous literature (Moody et al., 2001), which agreed with some of the anger-related and strength-related emotional terms selected in this study. Demattè et al. (2006) also found that when fabric swatches were presented with lemon odor, they were rated significantly softer compared to when they were presented with animal-like odor, reminescent of animal-made leather material used in leather sleeves. Nylon, polyester, and linen sleeves were markedly associated with high-energy active terms, such as “active”, “awake”, and “jump start”, as well as terms related to surprise, such as “disappointed”, “nervous”, and “off balance”. Interestingly, the hand-feel textural attributes of these sleeves were noticeably different, which could imply that these emotional associations were most possibly not due to the similarities of the sensorial attributes. These three materials were rated between 4.61 to 5.40 (“slightly unfamiliar” to “neither unfamiliar nor familiar”) on a 9-point scale in terms of familiarity. This indicated that the participants were somewhat familiar with the hand-feel sensory properties of these sleeves. Although they were somewhat familiar, it was possible that they were not familiar with the application of these materials as cup sleeves in a coffee drinking scenario, resulting to surprise-related emotional terms. Cotton, which is a commonly used material for clothing, was more associated with “satisfied”, “pleasant”, “comfortable”, “peaceful”, and “content” in cup sleeves application. Due to the association of the material to comforting clothing and the soft sensorial attribute of the material itself, this touch-emotion association were unsurprising. Similarly, suede, wool, and towel sleeves were found to be associated with affectively positive emotions, e.g., “fulfilling”, “joyful”, “merry”, “pleased”, “rested”, “rewarded”, “soothing”, and “special”, most likely due to the soft and fluffy-like nature of the fabrics. In addition, suede and felt are non-woven fabrics, which typically display smooth quality. In agreement with the emotional terms used in the present study, Moody et al. (2001) found that velvet or suede fabrics evoked feelings of “happy”, “loving”, “sensual”, “sleek”, “sophisticated”, “extravagant”, “reflective”, and “spiritual”. As can be observed here, the softer and more malleable the sensorial qualities of the materials were, the more positive emotional terms were deemed to be evoked.

Considering the observation that emotional responses evoked exhibited a possible relation to the sensorial qualities of the hand-feel texture attributes, it was also unsurprising that the matching responses to the four basic tastes and coffee-related flavors could also be explained by such association. With cardboard sleeves being the standard material for coffee cup sleeves in everyday life and being the most familiar in terms of hand-feel textures, participants understandably associated bitter taste and black coffee flavor the most with this sleeve material. On the other hand, soft and smooth textured towel fabrics were more matched with sweet taste and creamy flavor, which in coffee beverage application, would be likened to latte beverages, in which the bitter taste of black coffee is typically masked by the creamy taste of creamers or milk. An interesting observation here was that these soft and smooth textures were associated with more positively affective taste of sweetness, and less intense negatively affective taste of bitterness typically associated with black coffee. Indeed, sweetness has consistently been positively associated with pleasure, while bitterness has been associated with displeasure (Rousmans et al., 2000; Bartoshuk & Klee, 2013). This observation could be connected to the roughness-smoothness effects noted by previous cross-modal studies where smooth-textured containers or food samples were rated higher in sweetness. Biggs et al. (2016) reported that participants rated biscuit samples higher in saltiness when biscuits were presented on plates with rougher finish, but when they were presented on plates with smoother texture, the samples were rated higher in sweetness. Although van Rompay et al. (2017) investigated the cross-modal association between angularity effects and taste perception, the researchers proposed the plausible explanation that this cross-modality could be drawn from daily interactions with natural and man-made objects. With regards to angularity effects, the logical cognitive process that guided the mind dictated that angular objects would pose more risk of harmful or painful sensations or more intense impressions on the human skin, while rounder objects would pose less risk of harm or produce a gentler and smoother impressions, which ultimately resulted in the connection that rounder objects were more associated with sweeter products and less intense flavors (Becker et al., 2011; Deroy & Valentin, 2011; van Rompay et al., 2017). In the present study, angularity effects were not expected to contribute to any of the observed results because the cup sleeves dimensions were kept constant for all sleeve materials. Nevertheless, cross-modal correspondence studies regarding angularity effects and taste perception showed that textural attributes perceived to potentially induce harm or be related with toughness or roughness would be more associated with negatively affective tastes, e.g., sour, bitter, salty, and higher in flavor intensity. This explanation was plausible for the observation in the present study, where linen sleeves were considered to match the most with saltiness, considered to be an unpleasant taste (Rousmans et al., 2000; Leterme et al., 2008), although there was no significant main effect of sleeve materials. Regarding sour taste, which has been considered to be a moderately positive and negative taste, silicone sleeves were rated to be best-matched with this taste quality. In previous literatures, sour taste has been reported to elicit both negative and positive facial reactions in humans (Steiner et al., 2001), and hedonically rated less than sweet but higher than saltiness and bitterness (Rousmans et al., 2000). Considering silicone exhibited pleasant smooth but unpleasant sticky hand-feel sensations, it was understandable that the participants rated this sleeve material to best match sour taste, which is also considered to be both pleasant and unpleasant.

The results from instrumental measurements showed that the different cup sleeves used in the present study exhibited different textural and physical attributes. More importantly, the results demonstrated that certain textural and physical attributes evaluated instrumentally could be correlated with emotional association data obtained. To the best of our knowledge, the present study provided the first empirical evidence that evoked emotions from hand-feel touch stimuli could be related to the physical characteristics of the stimuli themselves, further supporting hypotheses proposed by previous literatures, such as hedonic matching (Demattè et al., 2006; Slocombe et al., 2016), familiarity effect, and context effect (Lawless & Heymann, 2010). In order to better characterize the different cup sleeve materials in terms of its physical attributes, a combination of measurements recorded using different instruments would have to be considered.

Firstly, fabric materials such as wool and towel were revealed to be thicker in characteristic, as shown by their high Sz readings as evaluated using the 3D Laser Scanning Confocal Microscope. Thicker material would imply that less heat would be conducted through the cup sleeve as it would provide more protective barrier against the heat during coffee consumption. Although the "temperature-premium effect" (Zwebner et al., 2013) might be expected, it must be noted that context effect might surpass such an effect in this scenario. As mentioned by Lawless and Heymann (2010), humans are highly susceptible to biases and are constantly adapting and comparing presented stimuli against other available stimuli in the environment. Due to the design and presented stimuli, i.e., coffee paper cup fitted with sleeves typically used in a coffee drinking setting, participants were biased into perceiving and evaluating the samples with the imagined scenario of their preferred coffee consumption environment. As such, it would be remarkably likely that the participants appraised the cup sleeves from a utilitarian perspective. In this present study, because thicker materials such as towel and wool would provide better protective barrier against the hot temperature of the coffee, these materials would appear more pleasant to hold the cup with, thus more associated with positive emotional terms, which agreed with the multivariate correlational results. To note, Sz was positively correlated with the following positive emotional terms: “fulfilling”, “good”, “joyful”, “merry”, “peaceful”, “pleasant”, “pleased”, “relaxed”, “rested”, “satisfied”, “soothing”, “special”, and “warm”, while negatively correlated with terms such as: “active”, “annoyed”, “disappointed”, “jolted”, and “social”. With these observations, it could be inferred that thinner materials such as stainless steel would yield the opposite trends and correlations. Previous findings regarding the association between textile product quality and hand-feel touch cues agreed with these findings of relating positive feelings with ease of comfort (Rahman, 2012).

Secondly, fabric materials such as wool and towel displayed better ability to be hand-held, i.e., better grip-ability. This deduction was created based on the high Sa, Spc, Sdr, and Sq values evaluated using the 3D Microscope. As Sa and Sq readings represent the presence of raised surfaces on the materials and how much these surfaces deviate from a completely level plane, respectively, it could be ascertained that fabric-based materials such as towel and wool were rougher based on their microstructures. However, the material slickness/slipperiness would not be able to be derived solely based on the Sa values. Slickness/slipperiness, which composes one-fifth of tactile perception, as suggested by Okamoto et al. (2013), could potentially be construed using the coefficient of friction readings. Moreover, Spc and Sdr readings depicted fabric materials such as wool and towel to possess raised surfaces of sharper tips and higher slopes. Although these readings indicated that these materials would be unpleasant to touch by consumers, it was possible that these materials would be considered low on the spectrum for these parameters, as the instrument used and its subsequent calculations were developed for other materials that would generate more extreme values. The Spc and Sdr readings for fabric materials such as towel and wool could possibly be at a point where they would be sufficiently sharp and raised to allow for comfortable and secure gripping of the cups.

From a utilitarian perspective, this would evoke more security in a coffee drinking context, and therefore, more positive emotional terms, which was indeed observed in the present study.

It must be noted that coefficient of friction could not imply grip-ability. According to the present data, although the 3D textural parameter Sa would suggest that fabric materials such as towel and wool would have the best grip-ability, the coefficient of friction data did not indicate this. Comparing the mean coefficient of friction values of the cup sleeve samples, leather cup sleeves rated the highest, while towel and wool were positioned in the middle of the spectrum, making them comparable to other cup sleeve materials. This discrepancy and apparent lack of relationship between coefficient of friction and Sa data could be attributed to the multidimensionality of tactile perception, as proposed by Okamoto et al. (2013), where Sa fell within the dimension of micro and macro roughness, while coefficient of friction fell within another dimension. Collectively, these dimensions would compose the overall tactile perception. In the present study, Sa would represent the microstructure of the materials, while coefficient of friction would be a better indication of the material slickness. Indeed, coefficient of friction was positively correlated with “balanced” and “satisfied”, suggesting better security with higher coefficient of friction values, and negatively correlated with “active”, “energetic”, and “grouchy”, suggesting higher high-action and negative emotions with higher coefficient of friction values. Another measured parameter in this study that would be an indication of the material property was deformation. The results showed that towel was highest in terms of deformation, while stainless steel was the lowest. This could provide an explanation as to why wool was not the most matched to sweet taste, a positively affective taste quality, but rather, towel was. Due to the higher deformation of towel fabrics, it could be inferred that towel would be more comfortable to hold than wool, although both fabrics shared similar measurements of other textural parameters.

3. Study 2: Influences of hand-feel touch cues on matching associations to consumed basic tastes

3.1. Materials and methods

3.1.1. Participants

Sixty-eight participants (36 females and 32 males) ranging in age from 19 to 66 years [mean age ± standard deviation (SD) = 40.1 ± 13.8] were recruited using the consumer profile database of the University of Arkansas Sensory Service Center. Participants self-reported no diseases or conditions that would affect their taste or hand-feel sensitivities. Participants also self-reported habitual consumption of at least one cup of coffee beverage per day.

To ensure that participants possess acceptable hand-feel stereognostic ability to distinguish between different sleeve textures (see below), the letters test was conducted in the same manner as described for Study 1.

3.1.2. Samples and preparation

The sleeve samples used in Study 2 were prepared and presented in the same manner as described in Study 1.

Bitter, salty, sour, and sweet taste solutions were prepared using 0.610g caffeine (Aldrich Chemical Company Inc., Milwaukee, WI, USA), 2.905g salt (Morton Salt Inc., Chicago, IL, USA), 0.685g citric acid (Sigma-Aldrich Fine Chemicals, St. Louis, MO, USA), and 43.07g sucrose (Wal-Mart Stores, Inc., Bentonville, AR, USA), respectively, diluted in 500mL of spring water (Mountain Valley Springs LLC, Hot Springs, AR, USA). As such, the concentrations of bitter, salty, sour, and sweet taste solutions were 0.122%, 0.581%, 0.137%, and 8.614% (w/v), respectively. These concentration levels were determined by and had been previously used in a cross-modal study by Wang et al. (2016). Intensity ratings by participants in the present study indicated that the bitter, salty, sour, and sweet taste solutions corresponded to 5.07 (± 2.08), 6.29 (± 1.23), 5.68 (± 1.65), and 6.47 (± 1.71), respectively, on a 9-point intensity scale ranging from 1 (extremely weak) to 9 (extremely strong).

Sleeve samples for instrumental measurement procedures for Study 2 were prepared in the same manner as those conducted in Study 1 as the data for analyses in this study were extracted from measurements performed in Study 1.

3.1.3. Procedure

Participants were given orientation for the study procedure and ballot prior to the study. Participants were then seated in individual sensory booths, and presented with a modified cardboard box containing an empty 12-oz. paper cup with the different sleeves fitted on. In addition, four basic-taste solutions were presented in 30-mL soufflé cups, respectively.

After touching each sleeve sample for 15 s, participants were asked to rate overall liking, familiarity of the hand-feel of the sleeve material, and matching of sleeve material to basic tastes. Overall likings of sleeve samples were rated on 9-point hedonic scales ranging from 1 (dislike extremely) to 9 (like extremely), while familiarity ratings were done on 9-point scales ranging from 1 (extremely unfamiliar) to 9 (extremely familiar). In addition, matching questions ("*How well does the texture or hand-feel of this cup sleeve match …?*") to four basic tastes (bitter, salty, sour, and sweet tastes) were answered on 9-point scales ranging from 1 (extremely unmatched) to 9 (extremely matched). In between tasting the four basic tastes, participants were asked to cleanse their palate using spring water (Mountain Valley Springs LLC, Hot Springs, AR, USA).

After completing the evaluation of the twelve sleeve samples, participants were asked to rate both overall likings and perceived intensities of the four basic taste solutions on 9-point hedonic, ranging from 1 (dislike extremely) to 9 (like extremely), and 9-point intensity scales, ranging from 1 (extremely weak) to 9 (extremely strong) respectively.

Instrumental measurement procedures for Study 2 followed those conducted in Study 1 as the data for analyses in this study were extracted from measurements performed in Study 1.

3.1.4. Statistical analysis

Data were analyzed using XLSTAT statistical software (Addinsoft, New York, NY, USA) and JMP Pro (version 13, SAS Institute, Cary, NC, USA). A two-way analysis of variance (ANOVA), treating "sleeve sample" and "panel" as fixed and random effects, respectively, was conducted to evaluate whether sleeve samples could differ with respect to overall liking, familiarity to the hand-feel of the sleeve materials, and degree of matching to basic tastes. Further, to better visualize the correlations between the sleeve samples and the basic tastes, PCA was performed on the standardized mean values of responses to basic taste matching questions of all cup sleeve materials. Additional PCA was also done to illustrate the associations of standardized means of basic taste matching of all cup sleeve materials to instrumental analyses. A statistically significant difference was defined to exist when $P < 0.05$.

Correlational analyses were conducted to evaluate correlational relationships between sensory cross-modal association data and instrumental data obtained from this study. Sensory data from the present study was used for these analyses instead of Study 1 data due to the higher reliability of sensory data evaluated with references in the form of the consumed basic tastes. As discovered by Ishii and O'Mahony (1990), participants perceived taste qualities differently when they were not allowed to consume the tastes as a form of reference. Since participants were provided with the basic taste solutions (bitter, salty, sour, and sweet), it would be expected that the cross-modal associations between hand-feel touch and taste cues in this study were higher in consistency and reliability compared to Study 1.

3.2. Results

The addition of basic tastes consumption to the procedure in Study 2 provided a form of reference for participants with respect to the basic taste qualities they were supposed to match with the textural qualities of the varying cup sleeve materials. As previously mentioned, the participants rated the bitter, salty, sour, and sweet taste solutions with the mean (± SD) ratings of 5.07 (± 2.08), 6.29 (± 1.23), 5.68 (± 1.65), and 6.47 (± 1.71), respectively, on a 9-point intensity scale ranging from 1 (extremely weak) to 9 (extremely strong). ANOVA results revealed that these intensity ratings were significantly different ($F(3,3260) = 411$, $P < 0.001$) (**Table 6**). Similarly, liking ratings of the 4 basic tastes were also rated to be significantly different to each other ($F(3,3260) = 115$, $P < 0.001$), with sweet taste being the most liked (mean ± SD = 6.68 ± 1.73) and the other 3 being scored less than 5, which corresponded to "neither dislike nor like", and therefore, negatively liked.

ANOVA output on the analysis of degree of matching associations to the four basic tastes (bitter, sweet, sour, and salty) showed that there was a significant main effect of cup sleeve materials for the four basic tastes, bitter, sweet, sour, and salty [$F(11,804) = 3.35$, $P < 0.001$; $F(11,804) = 2.19$, $P < 0.05$; $F(11,804) = 1.73$, $P < 0.05$; $F(11,804) = 1.47$, $P < 0.05$ respectively] (**Table 7**). More specifically, Tukey's HSD pairwise comparison tests indicated that cardboard sleeves were deemed to match bitter taste the most and were also the most familiar in terms of hand-feel textural attributes. Towel sleeves matched sweet taste the most, and were the most liked based on hand-feel texture. Interestingly, with regards to sour taste, rayon and stainless steel were deemed to be the most well-matched with this taste quality, which illustrated a different trend of association compared to Study 1. Another discrepant result was that there was a significant main effect of cup sleeve materials for matching association to salty taste, where there was none in Study 1. In line with the results of matching to salty taste in Study 1, linen sleeves were considered to match salty taste the most. Again, PCA bi-plots supported the results of ANOVA, showing bitter taste to be most associated with cardboard, sweet taste with towel and suede, sour taste with silicone, and salty with linen (**Figure 6**). Moreover, the bi-plots revealed that 78.20% of the total variation in the data varied with respect to the different cup sleeve materials. In fact, the relationship between cup sleeves and basic tastes were markedly clearer in Study 2 bi-plots compared to Study 1.

Correlation analyses revealed that some correlations existed between each of the 3D Microscope texture parameters, as well as the degree of basic taste matching associations from Study 2 (**Table 8**). Sa and Sz were shown to have significant positive correlations with each other, Spc, Sdr, and Sq, and negative correlations with sour taste matching. Positive correlation between Sa and Sz, and sour taste matching implied that the thicker the material, the less likely it would be associated with sour taste. Str was shown to positively correlate with bitter taste matching, which indicated that the more uniform the surface of the material was, the more likely it would be associated with bitter taste. Spc correlated positively with Sdr, Sq, and sweet taste matching, and negatively correlated with sour taste matching. The correlation trends for Sdr closely followed those of Spc. These correlations proposed that the rounder the peaks of the material surface and the lower the slopes of the peaks of the material surface, the more likely it would be associated with sour taste and less likely it would be associated with sweet taste. Finally, Sq was negatively correlated with sour matching, which mirrored the trends observed for Sa, as anticipated. No significant correlations between the UTM parameters, i.e. maximum deformation and coefficient of friction, and basic taste matching were observed.

3.3. Discussion

Study 2 was designed to standardize participants' interpretation of the four basic tastes in a cross-modal study regarding touch and taste perception within the context of coffee drinking experience. As well noted in previous literatures, people define tastes subjectively, as they have different forms of references and associations that they relate the tastes to. Existing studies revealed that people tend to confuse basic tastes, namely bitter-sour although sour-salty was also noted, when describing basic taste solutions (Meiselman & Dzendolet, 1967; O'Mahony et al., 1979). This tendency could simply be rectified by providing basic taste references for consumption to clearly define the taste qualities (O'Mahony et al., 1979). Thus, the results of Study 2 would be hypothesized to yield significant main effects of cup sleeve materials on more basic tastes association. As anticipated, the results of Study 2 again provided empirical evidence of cross-modal association between touch and taste, similar to Study 1. The trends observed in Study 2 generally imitated those in Study 1, but due to the inclusion of actual basic tastes in the procedure, there was expectedly significant main effect of cup sleeve materials on more basic tastes association, i.e., significant main effect of sleeve materials on salty taste matching in Study 2, where there was none in Study 1. In addition, the PCA bi-plot in Study 2 also showed clearer associations between cup sleeve materials and basic tastes compared to that of Study 1. Following the procedure used by Wang et al. (2016) to create the basic taste solutions, it was predicted that the intensity ratings for the basic taste solutions would not be significantly different, which disagreed with the results of the present study. However, as the intensity ratings for all four basic tastes were in between 5 to 6 ("neither weak nor strong" to "slightly strong"), this showed that the participants could easily distinguish the taste qualities to use as references during sleeve evaluation.

In Study 2, the sleeve materials best matched with sour taste was noticeably different than those observed in Study 1. Here, rayon and stainless steel were associated the most with sour taste, whereas silicone was associated the most with this taste quality in Study 1. Following similar possible explanation as Study 1, rayon and stainless steel possessed both pleasant smooth but unpleasant sticky hand-feel sensations, which concurred with sour taste that had been considered both pleasant and unpleasant (Rousmans et al., 2000; Steiner et al., 2001). It must also be noted that rayon, stainless steel, and silicone were the most disliked in terms of hand-feel sensations. Hedonic matching, i.e., sensations from one sensory modality considered pleasant (or unpleasant) would be associated more with sensations from another sensory modality considered equally pleasant (or unpleasant), had been proposed in previous cross-modal studies regarding touch and other sensory modalities to explain the existence of cross-modal associations (Demattè et al., 2006; Slocombe et al., 2016). However, it would be careless to deduce hedonic matching to be the explanatory reasoning behind the observed trends, because the aforementioned sleeves did not match the hedonic evaluation of sour taste, which was liked more than bitter and salty in this study. Therefore, another explanation must be offered regarding cross-modality between hand-feel touch and taste, which will be discussed in the next section.

As was the case of Study 1, the results from correlational analyses between instrumental measurements and degree of basic taste matching in the present study showed that the different cup sleeves used in the present study revealed that certain textural and physical attributes evaluated instrumentally could be correlated with sensory cross-modal data obtained. Like Study 1, the findings of the present study provided the first empirical evidence that sensory perception from hand-feel touch stimuli could be related to the physical characteristics of the stimuli themselves, in this case, cup sleeve materials.

Following the results of Study 1, Study 2 showed that some correlations existed between some of the instrumental parameters and the degrees of basic taste matching. Specifically, Spc and Sdr were positively correlated with sweet taste matching, and negatively correlated with sour taste matching. Considering that Sa and Sq also negatively correlated with sour taste matching, these results, in combination, supported the sensory results from the present study, where stainless steel, which was most matched with sour taste, consistently had the lowest Sa, Spc, Sdr, and Sq values. Likewise, towel, which was most matched with sweet taste, consistently had the 2 highest Sa, Spc, Sdr, and Sq values.

In this study, hedonic matching could not be assumed to occur, as not all the cup sleeve materials that were considered positively affective in Study 2 exhibited textural attributes considered to be contextually useful in a coffee consumption experience. Rather, it would be more likely that the consumers were prejudiced to assess the cup sleeve materials from a contextual, utilitarian perspective of how comfortable or secure they would be in a coffee drinking setting. Moreover, the consumers would also be tended to appraise the samples under the influence of familiarity effect. As can be seen with the example of cardboard, despite sharing similar textural attributes to stainless steel which was rated the lowest in terms of liking of its hand-feel, cardboard was rated one of the highest in terms of liking. This suggested that although the textural characteristics of cardboard did not imply that it would allow comfortable and secure holding of the coffee cup, cardboard was still considered to be affectively positive in terms of its hand-feel because of the consumers' high familiarity with cardboard as the most common cup sleeve material currently available in the industry. Additionally, despite exhibiting no significant differences with respect to the varying cup sleeves, there was a significant positive correlation between Str and bitter taste matching. Looking at the Str values of the different cup sleeves, cardboard and cotton generated the two highest values, suggesting that these materials exhibited the two most uniform surface texture patterns. This positive correlation supported the sensory cross-modal findings of the present study, where cardboard was most matched with bitter taste.

4. General discussion

The present studies demonstrated the existence of cross-modal association between hand-feel touch and gustatory cues. The empirical evidence showed that certain textural attributes sensed by active exploration of the hands could be related more to certain basic tastes and emotional terms in the context of coffee drinking experience. Specifically, bitter taste (Studies 1 and 2) and black coffee flavor (Study 1) were most matched with cardboard sleeves, while sweet taste (Studies 1 and 2) and creamy flavor (Study 1) were most matched with towel sleeves. Meanwhile, sour taste was most associated with silicone (Study 1), and stainless steel (Study 2). Although no significant main effect was displayed in Study 1, linen sleeves were most associated with salty taste in both Studies 1 and 2. To the best of our knowledge, this study also provided the first empirical evidence of correlational relationships between instrumental textural measurements, and sensory perception and evoked emotions from hand-feel touch stimuli.

Numerous suggestions had been proposed to explain the occurrences of cross-modal association in touch and taste perception. Among the most mentioned was hedonic matching (Demattè et al., 2006; Slocombe et al., 2016). Indeed, the findings of Slocombe et al. (2016) seemed to point towards this theoretical assumption, as they discovered higher numeric ratings for sourness and bitterness, both generally considered to be affectively negative tastes, in rougher-textured food samples. In the case of the present studies, hedonic matching did not necessarily occur. Although hedonically negative, bitterness was most associated with cardboard sleeves, which were not rated affectively negative, possibly in part due to the familiarity effect. Familiarity effect, i.e., multi-modal associations towards pleasantness or unpleasantness based on familiarity of the experience, is a learned process. Previous cross-modal studies regarding touch cues and other sensory modalities also posited that the multi-modal association could have been formed on the basis of learned experiences and association through every day life (Demattè et al. 2006; Slocombe et al., 2016). However, although familiarity to the hand-feel textural attributes could provide a plausible explanation for the trends observed in this study, it could not be considered as a strong contributor, given that nylon, polyester, and linen sleeves evoked high-energy active and surprise-related emotional terms despite the participants' slight familiarity with the hand-feel textural characteristics. As such, the current proposition was that the aforementioned explanations were plausible, but they must be considered concurrently with the context of the experience. This context effect was clearly illustrated in Study 3, where it was revealed that the participants' cross-modal association between hand-feel touch and taste stimuli, as well as the evoked emotions were related more to the utilitarian perspective of the physical attributes of the cup sleeves. Specifically, when the cup sleeve materials provided some protective barrier against the heat and sufficient roughness, the materials were more positively correlated with positive emotional terms and sweet taste. Contrastingly, these materials were negatively correlated with negative and high-energy emotional terms, representing negative consumer perspective of how the materials would function in a coffee drinking setting. In addition, the design of the present study inherently biased the participants towards evaluation under the contextual situation of coffee drinking experience, provided by the presentation of coffee cups and cup sleeves. Therefore, the trends and associations observed in this study should be noted with this consideration in mind. This contextualization would incline participants to appraise the cup sleeves with regards to their usefulness, pleasantness, and rightfulness (Ortony et al., 1988) in a coffee drinking scenario. As such, it would be reasonable to assume that the emotional responses and matching associations evoked by cup sleeves evaluation could be influenced by the participants' judgments of the functionality and applicability of the cup sleeves in everyday life. For example, although cardboard sleeves were not as highly liked as linen in terms of hand-feel sensations, cardboard sleeves were the most familiar. This illustrated cross-sensory associations learned from multi-modal cues in the environment from everyday life, where cardboard sleeves, being the standard material available for coffee cup sleeves, are already known to be safe, reliably functional sleeve materials. This was in conformance to the findings of Ng et al. (2013), in which the researchers found that the extrinsic properties of a product, i.e., cup sleeves in the present study, had a stronger association with abstract/functional connotations. In addition, McCabe and Nowlis (2003) suggested that participants' reliance on hand-feel touch cues depended on the product being evaluated, i.e., according to the context of how the product is normally used or consumed. Although this context effect may appear to limit the breadth of the conclusion of the present study, it should be noted that this actually allowed for more ecologically valid data (Stelick & Dando, 2018). As suggested by Spence (2011), there may be multiple mechanisms simultaneously at play to support the various manifestations of cross-modal correspondences. Thus, the above theories could very well function simultaneously to generate crossmodal association in touch and taste perception. However, further research to determine the extent of how dominant context effect is over hedonic matching would need to be done in the future. In addition, due to the clear context effect in the present studies, it would be necessary to conduct similar procedures in other food or beverage consumption scenario.

It should also be noted that this study further supported the results of previous findings that emotional measurements evoked from product experience provide a more precise perspective on why consumers dislike or like a product, and deeper views on consumer perception of a product (Gutjar et al., 2015; Samant et al., 2017). Often, questionnaires or ballots, without more convoluted procedures such as interviews or focus groups, restrict participants to truly describe their opinions and feelings about a product. In the present study, the addition of CDE CATA enabled the participants to select all the emotional terms that the deemed best match specific sleeve textural attributes. Using this procedure, it was observed that despite being rated similarly in liking, cotton and leather fabrics evoked extremely different emotions. This was in agreement with the findings of Ng et al. (2013), who similarly observed that the addition of emotional CATA procedure clearly distinguished products more effectively than hedonic ratings.

Additionally, it must be noted that the present study did not consider the individual variation in the tendency to touch a product for pleasure. As established by Peck and Childers (2003), the "Need-for-Touch" scale showed that a certain portion of participants have a greater tendency to touch a product for more than just evaluative purposes, but because they simply want to. Krishna and Morrin (2008) discovered that these personal tendencies resulted in differences in the degree that individuals would be affected by cross-modal correspondence or sensation transference. As such, future studies assessing the cross-modal influences should integrate these individual differences in the tendencies to touch.

Another remark that must be considered in the present study was that because the instruments used for the textural attribute measurements, i.e., 3D Laser Scanning Confocal

Microscope and UTM, were not specifically designed for fabric and cup sleeve material measurements and thus the parameter readings were generally low on the spectrum, it would be interesting to further explore how more extreme parameter readings would correlate with sensory perception and evoked emotions.

5. Conclusion

The findings of the present studies provided empirical evidence of the existence of cross-modal association between hand-feel touch and taste cues, as well as the first empirical evidence of correlational relationships between instrumental textural measurements, and sensory perception and evoked emotions from hand-feel touch stimuli in the context of a coffee consumption experience. Specifically, hand-feel touch stimuli were presented in the form of varying coffee cup sleeve materials. The results showed that certain sleeve materials were found to best match certain basic tastes and coffee-related flavors, illustrating cross-modal association between two separate sensory modalities. Furthermore, different sleeve materials with different textural characteristics evoked different emotional profiles. These results also demonstrated that certain textural parameters measured instrumentally significantly correlated with the sensory cross-modal association results. In particular, thicker and rougher materials such as towel and wool, were positively correlated with positive emotional terms and sweet taste, while thinner and smoother materials such as stainless steel were positively correlated with negative and high-energy emotional terms and sour taste. The observations and trends ascertained from the results of this study exemplified the dominance of context effect and familiarity effect over hedonic matching in the framework of cross-modal association between hand-feel touch and taste cues. However, despite possible explanations provided by previous research, exact theoretical explanation of the observed results still awaits further research. In particular, research into the neural mechanisms that underlie cross-modal association between hand-feel touch and taste perception are currently lacking. The findings of this study highlighted the importance of hand-feel touch cues in product evaluation and significance of product packaging or container material, which would hopefully motivate food and beverage professionals to incorporate more hand-feel touch cues in product packaging and container designs, as well as engage in a more careful selection of packaging and container materials.

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Appendices

Table 1. Materials used to prepare cup sleeves.

Sleeve materials	Manufacturers
Cardboard	Sugarman Creations, LLC. (Wilmington, DE, USA)
Cotton	Joann Fabrics and Crafts (Hudson, OH, USA)
Leather (cow)	Reed Sportswear (Detroit, MI, USA)
Linen	Ralph Lauren (New York, NY, USA)
Nylon	Mood Fabrics (New York, NY, USA)
Polyester	Joann Fabrics and Crafts (Hudson, OH, USA)
Rayon	Rag & Bone (New York, NY, USA)
Silicone	Small Parts, Inc. (Miramar, FL, USA)
Stainless steel	3M (Maplewood, MN, USA)
Suede	Mood Fabrics (New York, NY, USA)
Towel	Mood Fabrics (New York, NY, USA)
Wool	Mood Fabrics (New York, NY, USA)

Table 2. Surface texture characteristics measured using 3D Laser Scanning Confocal Microscope and their definitions.

Surface Parameters	Parameter Abbreviations	Definitions
Arithmetical mean height	Sa	Absolute value of "the difference in height of each point compared to the arithmetical mean of the surface"
Maximum height	Sz	"Sum of the largest peak height value and the largest pit depth value within the defined area"
Texture aspect ratio	Str	"Uniformity of the surface texture"; smaller value = more uniformity
Arithmetic mean peak curvature	Spc	"Arithmetic mean of the principal curvature of the peaks on the surface"; smaller value = points of contact with other objects are rounder
Developed interfacial area ratio	Sdr	"Percentage of the definition area's additional surface area contributed by the texture as compared to the planar definition area"; completely level surface = 0
Root mean square height	Sq	"Root mean square value of ordinate values within the definition area. It is equivalent to the standard deviation of heights"

Source: "Introduction to Roughness", by Keyence Corporation, retrieved June 17, 2018: https://www.keyence.com/ss/products/microscope/roughness/index.jsp

Table 3. Mean ratings (± standard deviation) of degree of matching to basic tastes (bitter, sweet, sour, and salty) and coffee-related flavors, and familiarity of cup sleeve materials on 9-point scales in Study 1.

	Bitter Taste	Sweet Taste	Sour Taste	Salty Taste	Creamy Flavor	Black Coffee Flavor	Familiarity
Cardboard	5.52_{a} (± 2.07)	5.36_{bc} (± 1.84)	4.28_{bc} (± 1.90)	4.56_{a} (± 1.82)	5.64_{bc} (± 1.99)	6.83_{a} (± 2.05)	7.55_{a} (± 1.51)
Cotton	4.55_{bcd} (± 2.01)	5.49_{abc} (± 1.95)	4.29_{bc} (± 1.94)	4.60_{a} (± 1.78)	5.82_{abc} (± 2.01)	5.61_{bcd} (± 1.84)	5.05_{bcd} (± 2.12)
Leather (cow)	5.02_{ab} (± 2.12)	5.11_{bc} (± 2.08)	4.50_{ab} (± 2.13)	4.79_{a} (± 1.88)	5.45_{bc} (± 2.16)	5.93_{b} (± 2.00)	5.22_{bcd} (± 2.31)
Linen	5.15_{ab} (± 2.15)	5.15_{bc} (± 1.99)	4.35_{bc} (± 1.98)	5.21_{a} (± 1.94)	5.25_{c} (± 2.12)	5.88_{bc} (± 2.03)	5.13_{bcd} (± 2.15)
Nylon	4.55_{bcd} (± 2.19)	5.47_{abc} (± 1.82)	4.27_{bc} (± 1.93)	4.55_{a} (± 1.74)	5.53_{bc} (± 2.05)	5.19_{bcde} (± 2.12)	5.40_{bc} (± 1.96)
Polyester	4.95_{abc} (± 2.17)	5.18_{bc} (± 1.93)	4.77_{ab} (± 1.90)	4.66_{a} (± 1.73)	5.11_{c} (± 2.13)	5.41_{bcde} (± 2.16)	4.61_{d} (± 2.12)
Rayon	4.54_{bcd} (± 2.13)	5.49_{abc} (± 1.98)	4.59_{ab} (± 1.98)	4.63_{a} (± 1.89)	5.74_{abc} (± 2.07)	5.09_{cde} (± 2.10)	4.94_{cd} (± 2.00)
Silicone	4.90_{abc} (± 2.34)	4.85_{c} (± 2.15)	5.13_{a} (± 1.99)	4.78_{a} (± 1.73)	5.17_{c} (± 2.28)	4.93_{de} (± 2.13)	5.14_{bcd} (± 2.25)
Stainless steel	4.56_{bcd} (± 2.34)	5.02_{c} (± 2.08)	4.76_{ab} (± 2.12)	4.74_{a} (± 1.81)	5.04_{c} (± 2.23)	4.78_{e} (± 2.07)	5.29_{bcd} (± 2.25)
Suede	4.17_{cd} (± 2.06)	5.86_{ab} (± 2.08)	4.14_{bc} (± 2.05)	4.41_{a} (± 1.86)	6.29_{ab} (± 2.00	5.25_{bcde} (± 2.08)	5.29_{bcd} (± 2.18)
Towel	3.73_{d} (± 2.19)	6.20_{a} (± 2.23)	3.64_{c} (± 1.99)	4.67_{a} (± 2.10)	6.50_{a} (± 2.18)	4.85_{d}e (± 2.20)	5.78_{b} (± 2.29)
Wool	4.68_{abc} (± 2.02)	5.66_{abc} (± 2.03)	4.18_{bc} (± 2.00)	4.84_{a} (± 1.78)	5.86_{abc} (± 2.26)	5.60_{bcd} (± 1.87)	5.23_{bcd} (± 2.18)

Subscripts indicate multiple pairwise comparisons results, where values not connected by the same subscripts are significantly different for each column at $P < 0.05$.

Table 4. Mean (± standard deviation) of instrumental parameters as measured using 3D Laser Scanning Confocal Microscope and Universal Testing Machine.

	Sa	Sz	Str	Spc	Sdr	Sq	Coefficient of Friction	Max. Deformation (μm)
Cardboard	1.82_{fg} (± 0.40)	15.05_{cd} (± 3.41)	0.41 (± 0.16)	407.39_{e} (± 49.0)	0.07_{b} (± 0.02)	2.27_{f} (± 0.51)	0.69 (± 0.07)	9.00
Cotton	13.23_{cd} (± 4.22)	143.61_{b} (± 36.16)	0.45 (± 0.13)	1463.08_{bcde} (± 269.39)	1.81_{b} (± 0.76)	18.17_{cd} (± 6.02)	0.67 (± 0.11)	6.50
Leather (cow)	17.68_{c} (± 1.49)	146.81_{b} (± 23.86)	0.24 (± 0.06)	2252.03_{bc} (± 251.36)	3.17_{b} (± 1.04)	21.82_{c} (± 1.94)	0.93 (± 0.13)	13.10
Linen	11.04_{cde} (± 0.48)	106.93_{bc} (± 14.85)	0.28 (± 0.10)	2542.02_{bc} (± 409.35)	2.79_{b} (± 0.27)	14.44_{cde} (± 0.52)	0.62 (± 0.06)	8.40
Nylon	3.68_{efg} (± 0.20)	30.88_{cd} (± 4.87)	0.36 (± 0.02)	520.33_{e} (± 96.73)	0.15_{b} (± 0.0)	4.58_{ef} (± 0.37)	0.53 (± 0.10)	12.10
Polyester	10.68_{cdef} (± 0.95)	90.08_{bcd} (± 12.92)	0.23 (± 0.01)	1430.51_{cde} (± 491.44)	1.06_{b} (± 0.18)	13.93_{cde} (± 1.96)	0.56 (± 0.09)	11.10
Rayon	8.51_{defg} (± 0.09)	60.05_{bcd} (± 2.01)	0.35 (± 0.19)	943.19_{de} (± 176.45)	0.48_{b} (± 0.11)	10.54_{def} (± 0.25)	0.83 (± 0.12)	10.50
Silicone	0.58_{g} (± 0.06)	4.79_{d} (± 0.24)	0.34 (± 0.12)	354.52_{e} (± 30.76)	0.04_{b} (± 0.00)	0.72_{f} (± 0.08)	0.53 (± 0.06)	8.50
Stainless steel	0.45_{g} (± 0.01)	3.95_{d} (± 0.09)	0.19 (± 0.09)	351.61_{e} (± 10.33)	0.04_{b} (± 0.00)	0.56_{f} (± 0.02)	0.23 (± 0.02)	5.70
Suede	16.15_{cd} (± 3.88)	136.58_{b} (± 29.39)	0.27 (± 0.05)	1718.39_{bcd} (± 248.46)	2.44_{b} (± 0.86)	19.82_{cd} (± 4.28)	0.68 (± 0.07)	8.20
Towel	27.91_{b} (± 7.22)	260.05_{a} (± 63.44)	0.33 (± 0.16)	3951.15_{a} (± 806.78)	10.44_{a} (± 1.41)	35.97_{b} (± 9.16)	0.68 (± 0.16)	12.90
Wool	45.14_{a} (± 4.84)	304.29_{a} (± 82.27)	0.37 (± 0.17)	2631.63_{b} (± 793.12)	11.42_{a} (± 3.08)	55.34_{a} (± 4.22)	0.63 (± 0.08)	10.60

Subscripts indicate multiple pairwise comparisons results, where values not connected by the same subscripts are significantly different for each column at $P < 0.05$.

Table 5. Multivariate correlational relationships between instrumental data measured using 3D Laser Scanning Confocal Microscope and Universal Testing Machine parameters, and proportions of selections of the Coffee Drinking Experience emotional terms obtained in Study 1.

	Sa	Sz	Str	Spc	Sdr	Sq	Coefficient of Friction	Max. Deformation
Active	-0.82	-0.79	-0.20	-0.65	-0.74	-0.81	-0.66	-0.41
Annoyed	-0.61	-0.68	-0.27	-0.69	-0.60	-0.61	-0.54	-0.33
Awake	-0.56	-0.57	-0.01	-0.44	-0.44	-0.56	-0.39	-0.43
Balanced	0.13	0.20	-0.22	0.40	0.05	0.13	0.68	0.13
Boosted	-0.45	-0.41	-0.31	-0.33	-0.44	-0.45	-0.30	0.05
Bored	-0.38	-0.40	0.48	-0.44	-0.41	-0.38	0.08	-0.21
Clear minded	-0.41	-0.40	-0.28	-0.30	-0.42	-0.42	-0.04	-0.05
Comfortable	0.81	0.88	0.28	0.80	0.81	0.82	0.43	0.24
Content	0.76	0.79	0.27	0.63	0.77	0.76	0.37	0.29
Curious	0.08	0.08	-0.37	0.08	0.05	0.08	-0.13	-0.06
Disappointed	-0.67	-0.72	-0.20	-0.69	-0.69	-0.68	-0.44	-0.24
Disgusted	-0.03	-0.07	-0.15	-0.11	0.03	-0.04	-0.10	0.03
Educated	0.32	0.27	-0.29	0.24	0.24	0.30	0.31	0.17
Empowering	-0.02	-0.01	-0.45	0.27	0.09	-0.03	0.02	0.07
Energetic	-0.40	-0.45	-0.67	-0.36	-0.38	-0.42	-0.63	-0.43
Free	0.01	0.09	0.17	0.11	0.06	0.02	0.23	-0.09
Fulfilling	0.58	0.66	0.07	0.60	0.65	0.59	0.04	0.02
Fun	0.17	0.22	-0.10	0.32	0.30	0.17	-0.02	0.28
Good	0.59	0.71	0.05	0.74	0.56	0.60	0.43	0.33
Grouchy	-0.40	-0.46	-0.04	-0.48	-0.30	-0.40	-0.59	-0.39
Guilty	0.07	0.05	0.58	-0.10	-0.10	0.07	0.53	-0.25
In control	0.03	0.03	-0.20	0.15	0.01	0.02	0.25	0.15

Values in red indicate significant correlations at $P < 0.05$.

Table 5. Multivariate correlational relationships between instrumental data measured using 3D Laser Scanning Confocal Microscope and Universal Testing Machine parameters, and proportions of selections of the Coffee Drinking Experience emotional terms obtained in Study 1 (Cont.).

	Sa	Sz	Str	Spc	Sdr	Sq	Coefficient of Friction	Max. Deformation
Jolted	-0.67	-0.71	-0.33	-0.68	-0.55	-0.68	-0.54	-0.37
Joyful	0.76	0.83	0.13	0.80	0.86	0.77	0.08	0.31
Jump start	-0.57	-0.58	-0.17	-0.40	-0.45	-0.58	-0.23	-0.41
Merry	0.57	0.68	0.07	0.77	0.69	0.59	0.14	0.17
Motivated	-0.35	-0.30	-0.24	-0.05	-0.28	-0.34	-0.19	0.04
Nervous	-0.40	-0.43	0.19	-0.52	-0.50	-0.39	0.04	-0.37
Off-balance	-0.38	-0.52	-0.11	-0.68	-0.47	-0.40	-0.24	-0.07
Peaceful	0.78	0.83	0.15	0.77	0.81	0.78	0.26	0.24
Pleasant	0.51	0.62	0.21	0.65	0.58	0.53	0.24	0.32
Pleased	0.71	0.73	-0.03	0.65	0.70	0.71	0.42	0.41
Productive	-0.29	-0.24	-0.32	-0.03	-0.32	-0.28	-0.15	-0.34
Relaxed	0.76	0.83	0.02	0.87	0.86	0.77	0.26	0.35
Rested	0.81	0.87	0.05	0.83	0.88	0.82	0.19	0.24
Rewarded	0.38	0.42	-0.33	0.46	0.33	0.37	0.42	0.25
Satisfied	0.70	0.76	-0.04	0.83	0.67	0.71	0.59	0.34
Social	-0.83	-0.86	-0.24	-0.77	-0.80	-0.85	-0.18	-0.14
Soothing	0.80	0.85	0.21	0.72	0.81	0.81	0.32	0.34
Special	0.47	0.50	-0.05	0.53	0.58	0.47	0.15	0.34
Understanding	0.06	0.08	0.33	0.18	0.16	0.06	0.35	0.15
Warm	0.87	0.93	0.23	0.86	0.93	0.88	0.32	0.35
Worried	-0.43	-0.40	-0.51	-0.50	-0.44	-0.18	-0.16	0.34

Values in red indicate significant correlations at $P < 0.05$.

Table 6. Mean ratings (± standard deviation) of intensity and liking of basic tastes (bitter, sweet, sour, salty) on 9-point scales.

	Intensity	Liking
Bitter	5.07_c (± 2.08)	3.54_c (± 2.29)
Sweet	6.47_a (± 1.23)	6.68_a (± 1.73)
Sour	5.68_b (± 1.65)	4.93_b (± 2.12)
Salty	6.29_a (± 1.71)	3.68_c (± 2.01)

Subscripts indicate multiple pairwise comparisons results, where values not connected by the same subscripts are significantly different for each column at $P < 0.05$.

Table 7. Mean (± standard deviation) of degree of matching to basic tastes (bitter, sweet, sour, salty), familiarity, and liking ratings of cup sleeve materials on 9-point scales in Study 2.

	Bitter Taste	Sweet Taste	Sour Taste	Salty Taste	Familiarity	Liking
Cardboard	6.06_{a} (± 2.09)	5.62_{ab} (± 2.18)	4.99_{ab} (± 2.13)	4.84_{ab} (± 2.19)	7.66_{a} (± 1.52)	5.84_{abc} (± 1.77)
Cotton	5.06_{ab} (± 1.98)	5.46_{b} (± 1.91)	4.66_{ab} (± 1.81)	4.60_{ab} (± 2.02)	5.00_{bc} (± 1.86)	5.96_{abc} (± 1.97)
Leather (cow)	4.81_{b} (± 2.02)	5.51_{ab} (± 2.06)	5.03_{ab} (± 2.01)	5.22_{ab} (± 2.17)	5.43_{bc} (± 2.15)	5.96_{abc} (± 2.14)
Linen	5.34_{ab} (± 2.00)	5.62_{ab} (± 1.83)	4.90_{ab} (± 1.99)	5.66_{a} (± 1.92)	6.09_{bc} (± 1.72)	6.50_{ab} (± 1.56)
Nylon	5.24_{ab} (± 1.66)	5.49_{ab} (± 1.89)	5.06_{ab} (± 1.59)	4.74_{ab} (± 1.83)	5.40_{bc} (± 1.82)	5.49_{bc} (± 1.94)
Polyester	4.57_{b} (± 1.90)	5.51_{ab} (± 1.91)	5.13_{ab} (± 1.79)	4.82_{ab} (± 2.06)	5.50_{bc} (± 1.91)	5.71_{abc} (± 2.00)
Rayon	5.19_{ab} (± 1.97)	5.40_{b} (± 1.98)	5.44_{a} (± 1.86)	4.88_{ab} (± 2.04)	5.16_{c} (± 1.99)	5.37_{c} (± 1.98)
Silicone	4.79_{b} (± 2.01)	5.24_{b} (± 2.31)	5.40_{ab} (± 2.05)	4.96_{ab} (± 2.05)	5.66_{bc} (± 2.28)	5.01_{c} (± 2.35)
Stainless steel	4.44_{b} (± 2.02)	5.51_{ab} (± 2.17)	5.53_{a} (± 1.86)	4.44_{b} (± 2.22)	5.29_{c} (± 2.22)	4.96_{c} (± 2.26)
Suede	4.82_{b} (± 1.86)	6.16_{ab} (± 1.52)	4.91_{ab} (± 1.78)	5.19_{ab} (± 1.97)	5.53_{bc} (± 1.94)	6.00_{abc} (± 1.93)
Towel	4.50_{b} (± 2.36)	6.53_{a} (± 2.06)	4.53_{b} (± 1.88)	4.96_{ab} (± 2.00)	6.25_{b} (± 2.05)	6.60_{a} (± 2.25)
Wool	5.03_{b} (± 2.12)	5.66_{ab} (± 1.88)	4.96_{ab} (± 1.77)	5.04_{ab} (± 1.78)	5.59_{bc} (± 1.95)	5.99_{abc} (± 2.03)

Subscripts indicate multiple pairwise comparisons results, where values not connected by the same subscripts are significantly different for each column at $P < 0.05$.

Table 8. Multivariate correlational relationships between instrumental data measured using 3D Laser Scanning Confocal Microscope and Universal Testing Machine parameters, and degree of basic taste matching obtained in Study 2.

	Sa	Sz	Str	Spc	Sdr	Sq	Coefficient of Friction	Max. Deformation	Bitter matching	Sweet matching	Sour matching	Salty matching
Sa	1.00											
Sz	0.97	1.00										
Str	0.13	0.15	1.00									
Spc	0.79	0.89	-0.05	1.00								
Sdr	0.94	0.94	0.13	0.85	1.00							
Sq	1.00	0.98	0.14	0.81	0.95	1.00						
Coefficient of Friction	0.32	0.36	0.29	0.39	0.20	0.32	1.00					
Max. Deformation	0.39	0.39	-0.03	0.46	0.41	0.39	0.55	1.00				
Bitter matching	-0.18	-0.23	0.61	-0.26	-0.21	-0.19	0.32	-0.00	1.00			
Sweet matching	0.47	0.58	-0.10	0.70	0.60	0.48	0.15	0.26	-0.22	1.00		
Sour matching	-0.60	-0.74	-0.35	-0.77	-0.65	-0.63	-0.38	-0.29	-0.05	-0.68	1.00	
Salty matching	0.35	0.40	0.00	0.58	0.29	0.35	0.52	0.14	0.19	0.23	-0.46	1.00

Values in red indicate significant correlations at $P < 0.05$.

Figure Legend

Figure 1. Modified cardboard boxes used in Studies 1 & 2 to prevent visual bias from the different cup sleeve materials.

Figure 2. PCA bi-plot based on correspondence analysis illustrating the associations of cup sleeve materials (blue) with emotional responses (red) in Study 1.

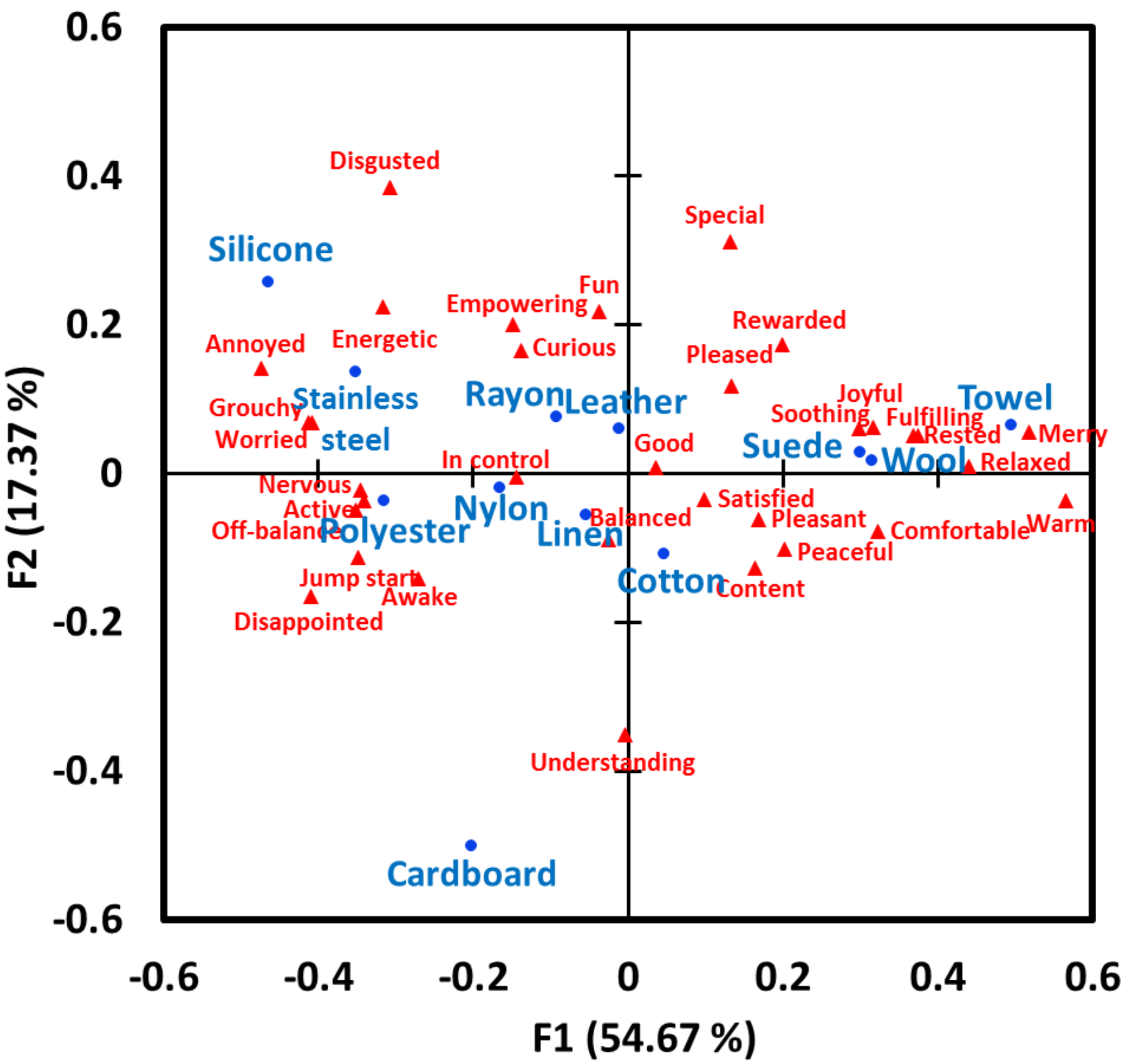
Figure 3. PCA bi-plot based on standardized means illustrating the associations of cup sleeve materials (blue) with “imagined” basic tastes (red) in Study 1.

Figure 4. PCA bi-plot based on standardized means illustrating the associations of cup sleeve materials (blue) with consumed basic tastes (red) in Study 2.

Figure 5. PCA bi-plot based on standardized means illustrating the associations of cup sleeve materials (blue) with instrumental parameters (red) and consumed basic tastes (green) in Study 2.

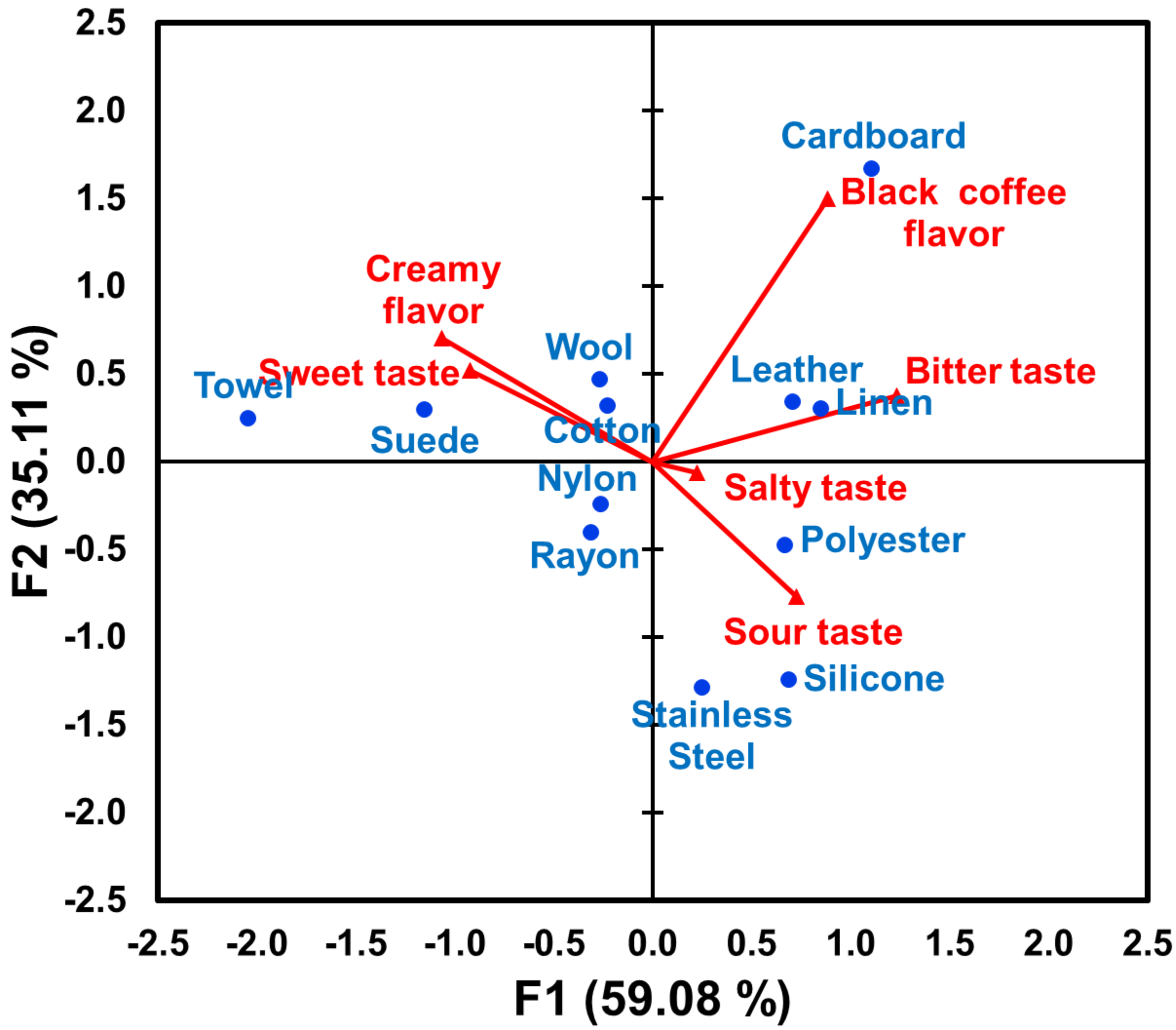
Figure 1.

Figure 2.



Disgusted
Special
Silicone
Fun
Empowering
Rewarded
Annoyed
Energetic
Curious
Pleased
Joyful
Towel
Grouchy
Stainless steel
Rayon
Leather
Soothing
Fulfilling
Rested
Merry
Worried
Good
Suede
Wool
Relaxed
In control
Nervous
Active
Nylon
Satisfied
Off-balance
Polyester
Balanced
Pleasant
Comfortable
Warm
Linen
Peaceful
Jump start
Cotton
Content
Awake
Disappointed
Understanding
Cardboard
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
F2 (17.37 %)
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
F1 (54.67 %)

Figure 3.



2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
F2 (35.11 %)
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
F1 (59.08 %)
Cardboard
Black coffee flavor
Creamy flavor
Wool
Towel
Sweet taste
Suede
Cotton
Leather
Bitter taste
Linen
Nylon
Salty taste
Polyester
Rayon
Sour taste
Silicone
Stainless Steel

Figure 4.

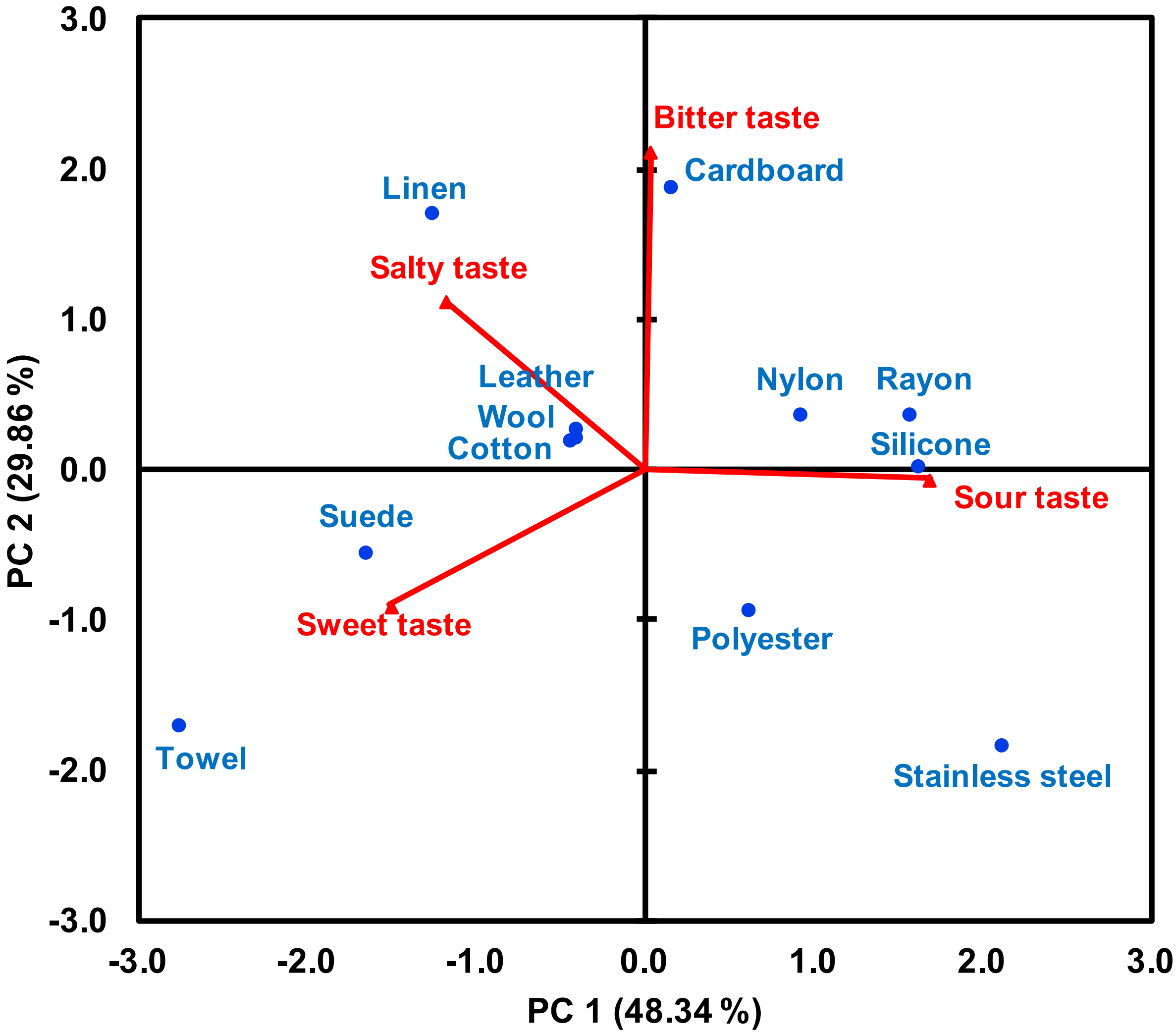
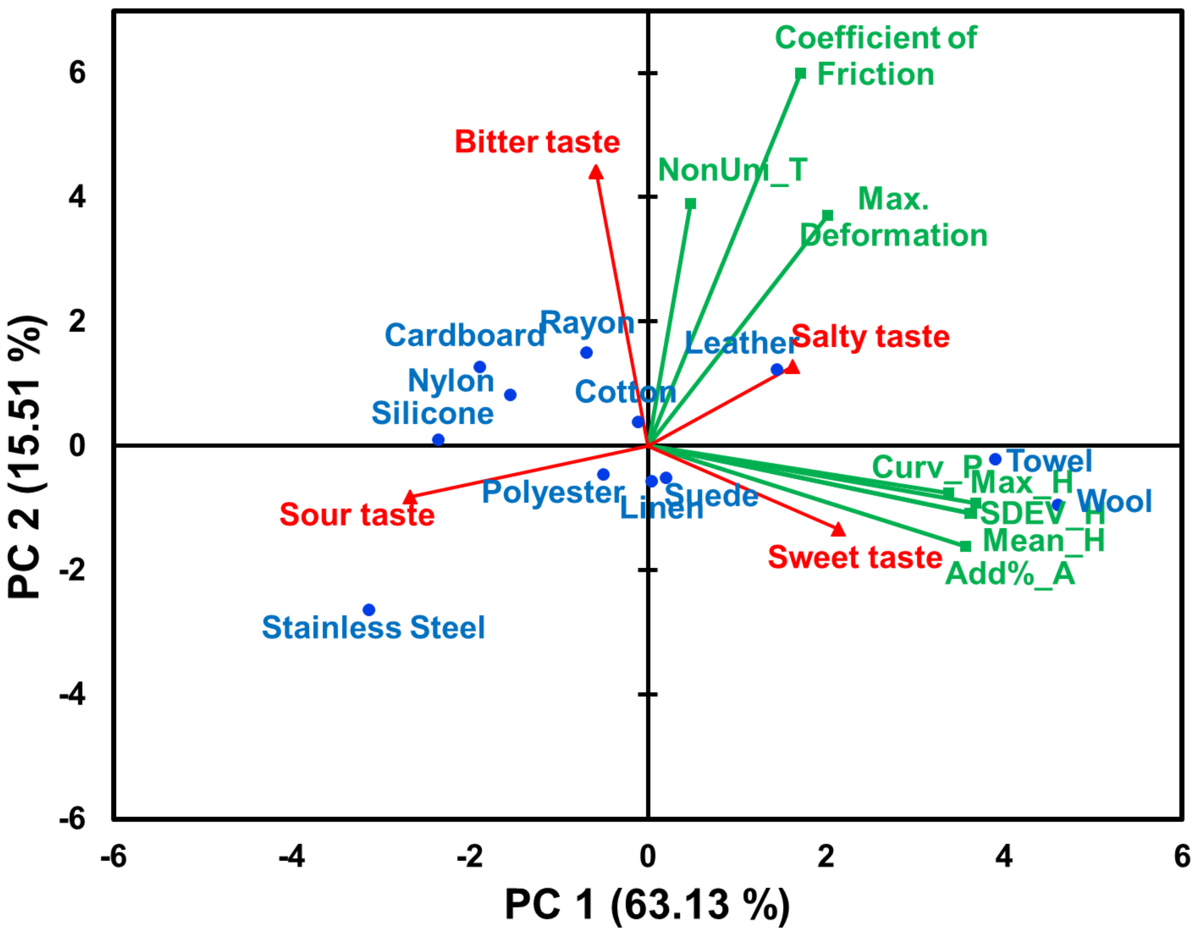

3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
PC 1 (48.34 %)
PC 2 (29.86 %)
Bitter taste
Cardboard
Linen
Salty taste
Leather
Wool
Cotton
Nylon
Rayon
Silicone
Sour taste
Suede
Sweet taste
Polyester
Towel
Stainless steel

Figure 5.


Coefficient of Friction
Bitter taste
NonUni_T
Max. Deformation
Cardboard
Rayon
Leather
Salty taste
Nylon
Cotton
Silicone
Curv_P
Towel
Max_H
Wool
SDEV_H
Mean_H
Add%_A
Polyester
Linen
Suede
Sour taste
Sweet taste
Stainless Steel
PC 2 (15.51 %)
PC 1 (63.13 %)
6
4
2
0
-2
-4
-6
-6
-4
-2
0
2
4
6

CHAPTER 5. Cross-modal influences of hand-feel touch factor on sensory perception and emotional responses toward brewed coffee

Abstract

Effects of extrinsic cues such as packaging or containers have been captured extensively in food and beverage applications. However, studies on the effects of hand-feel touch cues in this field had been underwhelming. The existence of cross-modal associations across hand-feel touch and taste cues was confirmed in the previous chapter. The next step is to determine whether the consumer experience of the cup sleeves could alter the intensities of emotional attributes evoked and sensory perception of brewed coffee presented with varying cup sleeve materials. Sleeves are frequently presented with beverages such as coffee, one of most frequently consumed beverages worldwide. This study, therefore, aimed to determine whether the degrees of emotional responses and sensory perception of brewed coffee could be influenced cross-modally by the emotional responses and sensory perception of the cup sleeve material. The procedure followed a between-group design of 3 treatment groups, in which a total of 120 qualified participants (67 F) with mean age (± SD) of 40.9 (± 16.2) years old evaluated 1 sleeve sample (towel, linen, or stainless steel) and 1 control (cardboard) regarding the intensities of emotional responses evoked and sensory attribute perception selected from the previous studies and chapter, as well as degree of arousal, valence, and matching on 9-point scales. It was found that brewed coffee presented with the sample materials were significantly perceived significantly, in terms of emotional response and sensory attributes, compared to the control (cardboard sleeve). Additionally, the sample sleeves also induced different emotional profiles than the control and from each other. Overall, the results and associations found in the present study closely followed those found in the previous chapter. Instrumental measurements and correlational analyses also supported these findings. Further, this study revealed that context effect and familiarity effect might contribute to the observed trends, in addition to hedonic matching in the context of cross-modal correspondence between hand-feel touch and taste cues. As highlighted in this study, touch cues are an important factor in product evaluation.

Keywords: touch, cross modal, emotional response, sensory attribute, coffee, sleeve materials

1. Introduction

Besides intrinsic product-specific characteristics, extrinsic non-product-specific characteristics can also influence consumer preference and purchase intent (Köster, 2009). Extrinsic non-product-specific attributes encompass packaging and container designs, which are increasingly becoming more novel and creative with the rapid advancement of technologies (Spence & Gallace, 2011). As the food and beverage industries become increasingly more saturated and competitive, it is of great importance for professionals in these industries to emphasize more efforts into creating packaging that prominently attracts consumers quickly (Milton, 1991; Wells et al., 2007). During a day-to-day product purchase scenario, the packaging design allows potential consumers to identify the type of product and brand, as well as communicate certain semantic meanings or reinforces existing associations towards the product before consumers decide to purchase it (Schifferstein et al., 2013). Particularly, for emotional food products such as chocolate, extrinsic cues such as food names and packaging details can elicit already existing emotional associations (Thomson et al., 2010). In this manner, the design of a packaging and the related sensory and emotional attributes elicited from the handling the packaging are of particular importance. The theoretical explanation for the association between sensations from one sensory modality and sensations from another modality could be attributed to "cross-modal correspondence" or sensation transference (Schifferstein, 2009; Spence, 2011). Because the packaging and content are presented in rapid succession during handling or consumption, people extract useful and meaningful information or associated connotations from the sensory cues of the packaging that can then build expectations towards the content of the packaging (Garber et al., 2001; Becker et al., 2011), which would consequently influence consumer expectations of intrinsic product-specific characteristics, and willingness to purchase (Rebollar et al., 2012).

Currently, manipulations of food product packaging have focused more exclusively on visual cues, i.e., colors, shapes, etc. as evaluated by vision. As consumers demand more immersive sensory experience in food and beverage consumption, it is imperative to seek other means to manipulate packaging designs to allow for a more uniquely attractive product. One such way is to change the hand-feel touch properties of packaging or container designs, as this is presently the least studied sense in the field of food and beverages. Hand-feel touch cues have been extensively studied in the field of textile and apparel design (Winakor et al., 1980; Alimaa et al., 2000; Cardello et al., 2003; Philippe et al., 2004; Grohmann et al., 2007, Jeguirim et al., 2010; Liao et al., 2016). However, researchers in the food and beverage fields have identified this particular sensory modality as an emerging and interesting area of research that could help companies in such industries to obtain a competitive edge in an increasingly saturated market. Previous research in this field has shown that hand-feel touch cues could influence participant perception of quality (Grohmann et al., 2007; Rahman, 2012), and flavor perception (Deroy & Valentin, 2011; Piqueras-Fiszman et al., 2011; Tu et al., 2015; Biggs et al., 2016; Slocombe et al., 2016; Cavazzana et al., 2017; Kampfer et al., 2017; Mirabito et al., 2017; van Rompay et al., 2017). In particular, this cross-modal association of product flavors with packaging or container shapes have demonstrated that generally, rounder packaging shapes are more closely associated with products that are sweeter (Deroy & Valentin, 2011) and less intense in taste (Becker et al., 2011). In another study, Biggs et al. (2016) revealed that rough vs. smooth plates could significantly influence consumer perception of biscuit sweetness, whereby biscuits presented in smooth plates were rated as sweeter than when they were presented in rough plates.

Moreoever, due to the close association between touch and emotions, as demonstrated by interpersonal touch cues, it would be expected that hand-feel touch stimuli would evoke some emotional responses (Knapp & Hall, 1997; Hertenstein & Keltner, 2006). Desmet (2010) proposed that a product can elicit emotional responses in an individual depending on its material qualities, its associated semantic connotations, and its functionality or performance. To evaluate these attributes, the evaluator must physically touch the product to derive meaningful information for evaluation purposes. Thus far, there has been limited research on the effects of hand-feel on food- and beverage-evoked emotional responses. From previous research, food- and beverage-evoked emotions could better predict consumer food choice rather than just liking ratings alone (Dalenberg et al., 2014; Gutjar et al., 2015). These previous research suggested that emotional responses could provide new information not captured by liking scores. As these findings showed that emotional responses could be affected by hand-feel touch stimuli, it would be of great interest to investigate if these stimuli could indeed influence emotional responses.

As was demonstrated in **Chapter 4**, hand-feel touch stimuli in the form of varying cup sleeve materials could induce taste and coffee-related flavor associations, as well as elicit different emotional responses in the context of a coffee drinking experience. In particular, cardboard was more associated with bitter taste and black coffee flavor, while towel was more associated with sweet taste and creamy flavor. Meanwhile, stainless steel was more associated with sour taste when the participants were provided with basic taste solution references, while linen was more associated with saltiness. The majority of the existing cross-modal correspondence research on the effects of extrinsic hand-feel touch cues have focused solely on the associations between 2 sensory modalities, but have yet to investigate the degrees of these associations. As such, the present study was designed to concentrate on the intensities of emotional and sensory attributes shown to be significantly associated with the hand-feel touch characteristics of certain cup sleeve materials, along with the degrees of valence and arousal, the 2 dimensions of emotions (Reinsenzein, 1994; Barrett, 1998).

This study was performed in conformance to the Declaration of Helsinki for studies on human subjects. The protocol used in this study was granted approval by the Institutional Review Board of the University of Arkansas (Fayetteville, AR, USA). Prior to participation, a written informed consent was obtained from each participant.

2. Materials and methods

2.1. Participants

A total of 123 participants (69 females and 54 males) were recruited through the consumer profile database of the University of Arkansas Sensory Service Center (Fayetteville, AR, USA). Using a pre-screening survey, all participants self-reported that they habitually drink one or more cups of coffee. In addition, participants self-reported no diseases or conditions that would impair their taste or hand-feel sensitivities.

To ensure that participants possessed acceptable hand-feel stereognostic ability to distinguish between different sleeve textures (see below), they were asked to identify a set of 8 wooden letters (Hobby Lobby, Oklahoma City, OK, USA). The procedure closely followed the "letters test" used by Luckett et al. (2016) with several modifications. Specifically, the modifications included using wooden alphabetical letters: A, I, J, L, O, T, U, and W (Essick et al., 1999) instead of confectionary letters. Another modification was that instead of asking participants to explore using their tongue intraorally, participants were asked to identify each letter placed on their non-dominant hand by freely exploring it using the fingers of their dominant hand. The letters were presented using a monadic sequential design. Their tactual stereognosis score was calculated as the number of correct answers out of 8. Qualified participants scored at least 6 out of 8. In the present study, 3 participants failed to qualify and their data were excluded from any analyses.

All participants were asked to refrain from eating, drinking (except water), and smoking cigarette for two hours prior to their participation to avoid potential influences of such activities on sensory perception (Cho et al., 2017).

2.2. Samples and preparation

Grounded roasted coffee beans (Southern Weather blend, Onyx Coffee Lab, Fayetteville, AR, USA) were brewed for 20 min using commercial coffee makers (Model DCC-2900, Cuisinart, East Windsor, NJ, USA) using a proportion of 90 g of ground coffee per 1,800-mL of spring water. Brewed coffee was poured into a 3,000-mL stainless steel dispenser (Bunn, Springfield, IL, USA) to maintain its high temperature. Brewed coffee was then poured into a 12-oz. paper cup, and cooled down to 65 (± 2) °C prior to serving.

Coffee preparation for surface temperature measurements followed the procedure for that of sensory measurements. Surface temperature reading of cup sleeves was conducted at brewed coffee temperature range of 60 °C to 70 °C using a standard hand-held thermometer for coffee temperature measurements and a temperature sensor (Mindfield® Biosystems Ltd., Gronau, Germany) for surface cup sleeve temperature measurements. Sample preparation for instrumental measurements for the present study followed those conducted in **Chapter 4; Study 1** as the data for analyses in this study were extracted from measurements performed in that study.

2.3. Selection of emotional and sensory attributes

Emotion and sensory attributes used in the present study were selected based on the findings of **Chapters 3** and **4**. Specifically, both emotion and sensory terms selected by at least 25% of the participants in both **Chapters 3** and **4** were selected (**Tables 2** and **3**). From **Chapter 3,** the emotional terms obtained using Check-All-That-Apply (CATA) procedure for brewed coffee that were selected by 25% of the participants were considered. Further, emotion terms in **Chapter 4** chosen by 25% of the participants for 4 of the cup sleeve materials shown to be most associated with the 4 basic tastes were considered. As a reference, cardboard was most associated with bitter taste and black coffee flavor, towel was most associated with sweet taste and creamy flavor, stainless steel was most associated with sour taste, and finally, linen was most associated with salty taste.

In the present study, the selected emotion and sensory terms were used to measure the degrees of intensity elicited by the brewed coffee samples as presented with the 4 cup sleeve materials, i.e., cardboard, towel, stainless steel, and linen.

2.4. Procedure

Sensory data collection followed a between-subject design, whereby an equal number of participants with similar demographics were selected to receive one treatment group. Within each treatment group, a participant evaluated 2 different sleeve materials: cardboard (control) and one of the other materials shown to be most associated with the three basic tastes in **Chapter 4**, **Study 2**, i.e., towel (associated with sweet taste), linen (associated with salty taste), and stainless steel (associated with sour taste). More detailed demographics information for each of the treatment groups can be found on **Table 1**.

An orientation for the procedure and ballot was given to each participant prior to the start of the study. Participants were seated in individual sensory booths, and presented with a coffee sample fitted with a cup sleeve covered with a modified paper cover. The purpose of the modified paper cover was to eliminate visual bias from visually inspecting the cup sleeve, while still allowing the participants to put both their hands on to the cup sleeve and drinking coffee from the cup. After touching each sleeve material with both hands for 15 s, participants then answered questions regarding the evoked emotions ("emotion" ballot; Ballot A), sensory attributes ("sensory" ballot; Ballot B), and degree of matching between cup sleeve material and the coffee consumed ("matching" ballot; Ballot C). Specifically, Ballot A focused on questions regarding the intensities of selected emotions ("annoyed", "awake", "bored", "calm", "comfortable", "content", "curious", "disgusted", "eager", "energetic", "good", "happy", "off-balance", "peaceful", "pleasant", "pleased", "relaxed", "satisfied", "soothing", "warm", and "wild").

The order of the emotion intensity questions was randomized. Ballot B required participants to answer questions regarding the intensities of basic tastes (bitter, salty, sweet, sour), coffee-related aromas (bitter and roasted), coffee-related flavors (burnt and roasted), and mouth-coating, as well as overall impressions (aroma liking, aroma intensities, flavor liking, mouthfeel liking, liking). Finally, Ballot C examined the intensities of arousal ("*How calm or aroused does the hand-feel of this cup sleeve make you feel?"*) and valence ("*How unpleasant or pleasant does the hand-feel of this cup sleeve make you feel?"*), as well as the degree of matching of the hand-feel of the cup sleeve material hand-feel to the presented coffee samples. All intensity questions were answered on 9-point scales (1 = "extremely weak" and 9 = "extremely strong), while liking questions were 9-point scales anchored with 1 = "dislike extremely" and 9 = "like extremely"). Matching questions ("*How well does the hand-feel of this cup sleeve match this coffee sample?*") were answered on 9-point scales ranging from 1 ("extremely unmatched") to 9 ("extremely matched"). Prior to the start of each ballot, participants were asked about their degrees of hunger and mood on 9-point scales to account for these 2 variables as potential confounding factors in the later analyses (1 = "extremely hungry" or "extremely bad" and 9 = "extremely full" or "extremely good"). For each ballot, participants were served a warm-up sample, then a randomized order of either cardboard first or one of the other cup sleeve materials first. To clarify, each participant evaluated 9 total samples, of which 3 were warm-ups (3 coffees x 3 ballots).

Another parameter measured was surface temperature of cup sleeve materials when coffee temperature was within the range of 70 °C to 60 °C. With regards to surface cup sleeve temperature measurements, brewed coffee was poured into a 12-oz. paper cup and left until coffee reached a temperature of 75 °C, as measured using a hand-held thermometer. The coffee was then poured into another 12-oz. paper cup fitted with a cup sleeve sample fastened with the temperature sensor positioned 27 cm from the bottom of the cup. Surface temperature readings began when coffee temperature reached 70 °C and continued until 60 °C. Relative humidity and ambient temperatures were recorded during surface temperature measurements using a sensor (Hobo Pro V2, Onset Computer Corporation, Bourne, MA, USA).

Instrumental measurement procedures for the present study followed those conducted in **Chapter 4** (**Study 1**) as the data for analyses in this study were extracted from measurements performed in that study.

2.5. Statistical analysis

Data were analyzed using XLSTAT statistical software (Addinsoft, New York, NY, USA), JMP Pro (version 13, SAS Institute, Cary, NC, USA), and SPSS 24.0 for Windows™ (IBM SPSS Inc., Chicago, IL, USA).

Paired t-tests were conducted to determine whether there were any significant differences between the degrees of intensities and liking ratings of emotional attributes, sensory attributes, arousal, valence, and matching among the cup sleeves in the treatment groups, i.e., control (cardboard) and one of the sleeve samples (towel, linen, and stainless steel). Differences of the means were calculated by subtracting control ratings from sample ratings. Two-way analysis of variance (ANOVA) treating "cup sleeve" as a fixed effect and "panelist" as a random effect was performed to compare the subtracted values (control ratings subtracted from sample ratings) of emotional, sensory, arousal, valence, and matching between the three cup sleeve treatments. Additionally, a one-way analysis of variance (ANOVA) was performed to determine whether the sleeve materials could differ with respect to surface temperature. In addition, one-way ANOVA was conducted to evaluate whether relative humidity and ambient temperature influenced surface temperature measurements.

To better illustrate the associations of cup sleeves with the degrees of intensities of emotion attributes, sensory attributes, arousal, and valence, principal component analysis (PCA) was conducted on the standardized means of values of ratings to the degrees of intensities of emotion attributes, sensory attributes, arousal, and valence among the cup sleeves (using grand mean ratings for cardboard from all treatment groups). In addition, agglomerative hierarchical clustering (AHC) using Ward's method was performed to classify the cup sleeves on their standardized means of ratings to the degrees of intensities of emotion attributes, sensory attributes, arousal, and valence. Further, correlation analyses were conducted to determine whether correlational relationships existed between degrees of intensities and liking of sensory measurements and physical measurements of the cup sleeves. Physical measurements of the cup sleeves included surface temperature measurements of the 4 cup sleeves used in the present study, as well as instrumental data measured using 3D Laser Scanning Confocal Microscope and Universal Testing Machine obtained from **Chapter 4 (Study 1)**.

3. Results

Paired t-tests comparing the degrees of intensities and liking ratings of emotional attributes, sensory attributes, arousal, valence, and matching of the three cup sleeves, and those of the control (cardboard) showed some significant differences for 9 emotional attributes, 4 sensory attributes, arousal, and valence at $P < 0.05$ (**Tables 4-6**). More specifically, the intensity ratings of coffee samples presented in towel sleeves were significantly different from those of cardboard ratings for the following emotional attributes: "bored", "content", "curious", "happy", "peaceful", "pleased", "relaxed", "soothing", and "warm". Linen cup sleeves displayed emotional intensity ratings that were significantly different from control sleeves in terms of "warm", and finally, stainless steel showed significantly different emotional intensity ratings from the control for "happy" and "peaceful". For all significant emotional attributes, all sleeve samples had higher means than those of the control, except for "bored", where towel elicited less boredom than cardboard. Observing the comparison results for the intensities of sensory attributes, towel was significantly different from the control in the following attributes: overall aroma liking, bitter taste intensity, and overall mouth-feel intensity, while stainless steel was significantly different from the control for roasted flavor intensity. Here, it was observed that the mean ratings for towel were higher than those of cardboard in terms of overall aroma liking and overall mouth-feel intensity, and lower with respect to bitter taste intensity. Also, stainless steel displayed lower ratings of roasted flavor intensity than the control. Finally, towel and linen showed significantly higher mean ratings for valence than cardboard, indicating that these materials were more pleasant in terms of their hand-feel. Meanwhile, towel was rated significantly less arousing than cardboard.

Analyses into the differences of means among the three cup sleeves resulted in significant differences in 6 attributes (“bored”, “warm”, overall aroma liking, bitter taste intensity, arousal, and valence) at $P < 0.05$ (**Table 7-9**). As a reference, the differences of the means were calculated by subtracting control ratings from sample sleeve ratings. Compared to the three cup sleeves, linen elicited the highest “bored” feeling, while coffee presented with towel sleeves elicited the highest “warm” feeling and was rated the highest in overall aroma liking. Meanwhile, coffee presented with stainless steel sleeves evoked the lowest “warm” feeling, was rated the least liked in overall aroma and hand-feel pleasantness, and was rated as the most arousing.

For better illustration of how the emotion attributes, sensory attributes, arousal and valence of coffee samples varied with respect to the various cup sleeves presented alongside the coffee, PCA bi-plots were generated (**Figures 1, 3, and 5**). Cardboard, as the control, unsurprisingly was not closely associated to any emotional attributes. Linen was closely associated with “annoyed”, “bored”, and “wild”. Towel was closely associated with mostly low-arousal feelings, such as “relaxed”, “soothing”, “peaceful”, and “content”, while stainless steel was closely associated with both negative and positive feelings. Among the positive feelings associated with stainless steel were “good”, “comfortable”, “happy”, “pleasant”, “pleased”, “warm”, “awake”. However, stainless steel also evoked the feeling of “disgusted”. AHC based on Ward’s method largely supported the PCA findings, whereby linen and cardboard were categorized together as a group, while stainless steel and towel were categorized as two other separate groups. In terms of the sensory attributes associated, cardboard was more associated with burnt flavor, bitter taste, and bitter aroma, whereas towel was more associated with mouth-coating, roasted aroma, sweet taste, and overall aroma. Meanwhile, stainless steel and linen were grouped together in the same quadrant, seen to be most associated with sour taste and salty taste. AHC dendogram (**Figure 4**) clearly illustrated similar trends, where towel and cardboard were classified as 2 separate groups, while linen and stainless steel were classified into 1 group. PCA on degrees of arousal and valence showed that valence was most associated with linen, suggesting that linen was the most pleasant, which agreed with the results of the ANOVA on the subtracted valence values in the linen group. Arousal was positioned in the same quadrant as stainless steel, which indicated that stainless steel was most arousing, although ANOVA results for the subtracted arousal values in the stainless-steel group were not significant. AHC dendogram illustrated the grouping of stainless steel and cardboard into one group, with linen and towel classified as two separate groups.

Sensor data measuring relative humidity and ambient temperature during surface temperature measurements showed no significant main effects ($P > 0.05$), which ensured consistent environmental conditions during temperature measurements. Comparing between the means of the surface temperatures of the different cup sleeve materials when coffee temperature ranged between 60 °C to 70 °C, as anticipated, there was a significant main effect of cup sleeve materials [$F(4,160) = 328$, $P < 0.001$]. More specifically, surface temperature of the cup fitted without a sleeve generated the highest value at 47.0 (± 1.26), while fabric-based thicker materials such as wool and towel scored the lowest at 33.6 (± 1.48) and 31.3 (± 1.20), respectively (**Table 10**). Interestingly, there appeared to be a significant main effect of cup sleeve materials on the time for coffee temperature to decrease from 70 °C to 60 °C [$F(4,10) = 6.08$, $P < 0.05$], implying that certain cup sleeve materials could better provide heat insulation to better maintain coffee temperature. Unsurprisingly, cups fitted with towel cup sleeves, being a thicker fabric material, yielded the longest time for product temperature to decrease from 70 °C to 60 °C (334 ± 1.67), while cups fitted without any sleeves took the shortest time (281 ± 6.81).

Observing the correlational relationships between physical measurements and sensory data, it was possible to discern a total of 18 significant correlations: 13 negative (3 for emotional attributes, 6 for sensory attributes, and 4 for arousal), and 5 positive (for sensory attributes) (**Table 11**). Looking at correlations for the degrees of emotion intensities, it was observed that the materials with less deformity evoked higher feelings of "awake" and "energetic", while materials with flatter surfaces evoked higher feeling of "wild". Here, these observations would suggest that materials such cardboard or stainless steel would show these relationships with emotional attributes. However, these were not reflected in the AHC dendogram and PCA bi-plot. In addition, correlational relationships between physical measurements and sensory attributes showed that materials with flatter or thinner surfaces, as reflected in low Sa, Sz, Sdr, and Sq, would likely to evoke higher bitter taste and lower roasted aroma intensities. Indeed, towel, which predominantly had higher Sa, Sz, Sdr, and Sq shown in **Chapter 4** results were associated with lower bitter taste and higher roasted aroma as illustrated by the PCA bi-plot (**Figure 3**). These relationships also implied that materials with less deformity would elicit higher sour and salty taste intensities, while materials with less rounded surface tips would be more associated with higher overall aroma liking. **Chapter 4** results showed that towel displayed one of the lower Spc values, implying less round surface tips, which as reflected by the PCA bi-plot in this study, was more associated with overall aroma liking. Additionally, observing the results of correlational analyses on arousal ratings and physical measurements, it was possible to see that materials with flatter or thinner surfaces, as indicated by the lower Sa, Sz, Spc, and Sq, would likely to evoke higher arousal.

4. Discussion

The present study was intended to be a continuation and development of the findings of **Chapter 4**. In **Chapter 4**, it was discovered that cardboard was most associated with bitter taste and black coffee flavor, towel with sweet taste and creamy flavor, linen with salty taste, and stainless steel with sour taste. Building upon these results, these four cup sleeve materials served as the treatments in the present study, with cardboard serving as the control, as it was found to be the most familiar in **Chapter 4** and currently the most commercially available material in the industry. This study examined how the three less commercially available materials could be perceived in terms of the degrees of emotional attributes, sensory attributes, arousal, valence, and matching to the coffee samples presented. Generally, the findings of the present study largely corroborated the findings of the previous studies in **Chapter 4**.

From the results of the paired t-test, it was determined that brewed coffee presented in the 3 cup sleeve materials, i.e., towel, linen, and stainless steel, generated higher intensities of certain emotional terms than the control. Here, towel sleeves evoked more significant emotional terms than linen and stainless steel. Interestingly, despite the surface temperature measurements of the 3 materials showing lower temperature than cardboard, paired t-test results of the 3 sleeves generated higher intensity of “warm” emotion. Instead of observing the emotional responses to mirror the sensory perception and physical attributes of the cup sleeve materials as was the case of Schifferstein (2009), the emotional association to “warm” in the present study could reflect the comfortability of the cup sleeve materials as a functional item. This was in conformance to the paired t-test results of the valence ratings among the three cup sleeve materials, where it was found that towel and linen showed significantly higher mean ratings than cardboard, indicating higher pleasantness than the control in terms of their hand-feel. Additionally, instrumental data, as well as correlational analyses connecting instrumental measurements and sensory data suggested that thicker materials like towel could possibly better maintain coffee temperature compared to other sleeves as it yielded the longest time for coffee temperature to decrease from 70 °C to 60 °C.

Moreover, the results of the comparison of sensory attributes as determined by paired t-test and ANOVA on the differences of means in the present study also partly agreed with the findings of **Chapter 4**. Brewed coffee presented in towel sleeves appeared to significantly lower in bitterness and higher in overall mouth-feel intensity than the control as established by the paired t-test and showed the lowest difference of means value despite yielding no significant differences, which implied that the panelists could be associated these more to creamier coffee beverages, e.g., latte, which would be lower in bitterness and higher in mouth-feel. Indeed, PCA bi-plot showed towel to be closely associated to roasted aroma and sweet taste, and in **Chapter 4**, towel was also most associated with creamy flavor and sweet taste, in addition to possessing higher Sa, Sz, Sdr, and Sq values, as mentioned in **Chapter 4**, which were associated with lower bitter taste and higher roasted aroma. This was also supported by the low arousal ratings for coffee samples served with towel sleeves, as this suggested that the association to a creamier coffee beverage would result in lower high-energy emotional terms, resulting in emotional terms such as "soothing" and "relaxed", as displayed by the PCA bi-plot (**Figure 1**). Moreover, as anticipated, PCA bi-plots also showed that cardboard was more associated with bitter taste, bitter aroma, and burnt flavor, agreeing with the findings of **Chapter 4**, in which cardboard was most associated with black coffee flavor and bitter taste. Similar to the explanation proposed in the previous studies, it was posited that the familiarity effect played a major role in biasing the participants towards associating cardboard sleeves with black coffee flavor and bitterness, which unsurprisingly resulted in the grouping of cardboard and linen in terms of emotional intensities, as linen was closely associated with "bored" in the PCA bi-plot. With regards to stainless steel sleeves, it was observed that this sleeve material evoked both positive and negative feelings, especially those of high-active emotions. Unsurprisingly, stainless steel elicited the most arousal as shown by the PCA bi-plot, paired t-test, and ANOVA comparisons. This could be attributed to the semantic expectations of stainless steel as a material to be colder than the other materials, despite not displaying the coldest surface temperature, as was reflected on participants rating stainless steel the lowest in terms of “warm” emotion. When humans are subjected to cold environments, the immediate physiological reaction would be to restore the balance of the body temperature. The metabolic immediate response pathway would involve an increase in metabolic rate, which would increase heat production resulting in shivering (van Ooijen et al., 2004). Ultimately, these would result in the feelings of being more “awake” as a response to the expectation and semantic association of a material being more cold. Lastly, linen seemed to be similarly characterized as cardboard, the control. Besides being associated with “bored” as shown in the PCA and grouped together with cardboard in terms of its emotional terms by the hierarchical cluster analysis, linen also elicited the highest “bored” rating and closely associated with salty taste despite showing no significant differences for paired t-test and ANOVA. Interestingly, linen also appeared to be most liked, i.e., highest valence, compared to the other materials including the control. Current instrumental measurements and correlational analyses unfortunately could not provide possible explanations for this, other than that linen must possess some other attributes, perhaps deemed useful in functionality and would raise its performance appraisal in the context of coffee drinking, that could not be captured by the instrumental capabilities of the equipments used in this study.

Previous research regarding cross-modal correspondence between hand-feel touch and taste perception had proposed several explanations for the observed trends, namely hedonic matching (Demattè et al., 2006; Slocombe et al., 2016). Although this hedonic matching and “temperature-premium effect” (Zwebner et al., 2013) might be expected, it must be noted that context effect might surpass such an effect in this scenario. As mentioned by Lawless and Heymann (2010), humans are highly susceptible to biases and are constantly adapting and comparing presented stimuli against other available stimuli in the environment. Due to the design and presented stimuli, i.e., coffee paper cup fitted with sleeves typically used in a coffee drinking setting, participants were biased into perceiving and evaluating the samples with the imagined scenario of their preferred coffee consumption environment. As such, it would be remarkably likely that the participants appraised the cup sleeves from a utilitarian perspective. In this present study, because thicker materials such as towel and linen would provide better protective barrier against the hot temperature of the coffee (shown by the low surface temperatures), these materials would be pleasant to hold the cup with (shown by the higher valence ratings compared to control), thus more associated with positive emotional terms, which agreed with PCA bi-plot illustrating the associations between cup sleeves and emotional terms for towel. With these observations, it would be expected that thinner materials such as stainless steel would yield the opposite trends. However, this was not the case in the present study, as stainless steel was notably most associated with high-energy positive feelings, despite rated the lowest in terms of valence, therefore making the hedonic matching theory unlikely as an explanation in this scenario. Additionally, linen was shown to be classified together with cardboard in terms of emotional and sensory intensities, as well as sharing the emotional term “bored”, despite showing the highest valence rating. This indicated that participants evaluated linen to be similar to cardboard in terms of the emotional and sensory attributes elicited, and therefore, under familiarity effect, perceived similarly as cardboard, resulting in no significant differences in majority of the attribute intensities. Therefore, the findings of this study demonstrated that the previous theories and suggested explanations for cross-modal correspondences involving hand-feel touch cues such as hedonic matching could not account for all cross-modal correspondence trends observed in this study. Rather, the plausible explanation might involve a combination of familiarity effect and context effect with a greater emphasis on the latter, as displayed by significant correlations between instrumental physical measurements and sensory data, suggesting utilitarian appraisal of the hand-feel touch stimuli in the context of coffee drinking. Further research would need to be done to confirm the contribution of these effects, as well as determine to what degree these effects could and would predict the observed cross-modal-influenced results.

With all this information, the question arises: *“Which cup sleeve material would be best for coffee beverages in the industry?”* To answer this, it is best to derive potential solutions from the results of the hierarchical cluster analyses. The dendograms based on these analyses showed that in terms of emotional intensities, cardboard and linen were similar, while stainless steel and towel were grouped separately as 2 different units. In terms of sensory attribute intensities, linen and stainless steel were classified similarly, while towel and cardboard were grouped separately. Stainless steel and cardboard were classified together in terms of arousal and valence intensities, while linen and towel were classified separately. Thus, the solution is that the most appropriate sleeve material depends on which responses are deemed more important in the product of interest – sensory or emotional, in addition to the cost and accessibility of the materials. Additionally, the familiarity of the material in terms of its hand-feel along with how well they perform in the context of coffee drinking would also contribute greatly to the acceptance and congruency of the coffee samples. From the present study, comparing all the sleeves, towel would be most appropriate if the intention was to reduce the perception of the bitter taste intensity in brewed coffee. Despite the findings of the present study, further research would need to be done to confirm the plausibility and applicability of these more novel materials as cup sleeves. Willingness-to-pay, interest, and willingness to replace cardboard as the cup sleeve used in everyday life, would need to be first investigated before any recommendations could be made.

Although the results of the present study extended those of the previous studies, it must be noted that this study did not account for the individual variation in the tendency to touch a product for pleasure. Peck and Childers (2003) established the “Need-for-Touch” scale, which successfully categorized participants into two types of individuals: one group who had a greater tendency to touch a product for pleasure in addition to appraise the product, and the other who simply touched the product only for evaluative purposes. Krishna and Morrin (2008) revealed the differences in the degree that individuals are affected by cross-modal correspondence or sensation transference could be dependent on these personal tendencies. Therefore, future studies assessing the cross-modal influences, especially to assess influences of hand-feel touch stimuli, should consider these personal differences in the tendencies to touch.

In addition, since the results of the present study showed the influence of some context effect, the cultural background of participants must be considered in future studies. Cultural differences in assessing events or objects and how they are perceived have been recorded extensively in numerous fields. Additionally, due to this context effect, it must be noted that the cross-modal differences observed in the present study must also be applied or investigated in contexts other than coffee drinking scenarios.

5. Conclusion

The findings of the present study provided extensive empirical evidence of cross-modal influences of hand-feel touch stimuli via varying cup sleeve materials on sensory perception of taste cues in the form of brewed coffee. Analyses of the current data suggested that overall, the trends observed here followed those of the cross-modal associations trends found in the previous chapter (**Chapter 4**). Notably, presenting brewed coffee with certain cup sleeve materials could alter the sensory perception of, and evoked emotional responses to, brewed coffee compared to the control of brewed coffee presented in cardboard sleeves, currently the most accessible sleeve material in the industry. Specifically, coffee served with towel sleeves significantly reduced the bitter taste intensity and was liked better compared to the control; it was additionally more associated with positive emotions of low-energy, sweet taste, and roasted flavor. Coffee presented in linen sleeves was rated the highest in terms of valence, despite being most associated with salty taste. Finally, coffee presented in stainless steel sleeves was shown to be most associated with sour taste, positive emotions, and high-energy emotions, e.g., "awake". Instrumental and physical measurements, i.e., surface temperature measured during product temperature range of 60-70 °C, also supported these deductions.

Like the previous chapter, this study emphasized the importance of hand-feel touch cues in product evaluation and the significance of product packaging or container material and design. These findings hopefully inspire professionals in the food and beverage industries to consider packaging or container designs more carefully, as well as to incorporate more varied hand-feel touch textural properties in their designs. These efforts may considerably help companies stand out in an increasingly competitive industry.

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Appendices

Table 1. Demographics information for the three treatment groups of cup sleeves.

	Towel	Linen	Stainless steel	Total
Female	22	22	23	67
Male	18	18	17	53
Age [mean ± SD]	43.0 ± 17.6	43.5 ± 15.5	36.2 ± 14.8	40.9 ± 16.2
Habitual consumption preference				
Black	14	14	14	42
Both creamer and sugar	12	14	14	40
Creamer	8	8	9	25
Sugar	6	4	3	13

Values reported for each of the cup sleeves groups are out of 40, while the total are out of 120.

Table 2. Mean (± standard deviation) of the degrees of intensity of emotional attributes among coffee samples in three treatment groups, i.e., presented with control (cardboard) and one of the three cup sleeve samples (towel, linen, or stainless steel).

	Groups											
	Towel				Linen				Stainless Steel			
	Towel	Control	t	p	Linen	Control	t	p	Stainless Steel	Control	t	p
Annoyed	1.83 (± 1.47)	2.48 (± 1.95)	-1.83	0.08	2.15 (± 1.35)	2.60 (± 1.88)	-1.62	0.11	2.08 (± 1.29)	2.68 (± 2.09)	-1.50	0.14
Awake	5.13 (± 1.94)	5.28 (± 1.81)	-0.55	0.58	5.63 (± 1.94)	5.43 (± 2.19)	1.00	0.32	6.08 (± 1.69)	5.95 (± 1.91)	0.63	0.54
Bored	2.10 (± 1.48)	2.70 (± 1.81)	-2.73	0.01*	2.33 (± 1.49)	2.05 (± 1.43)	1.34	0.19	2.15 (± 1.29)	2.28 (± 1.68)	-0.51	0.61
Calm	5.03 (± 2.06)	4.35 (± 1.69)	1.96	0.06	4.80 (± 2.04)	4.80 (± 1.77)	0.00	1.00	5.13 (± 1.83)	4.85 (± 2.23)	0.75	0.46
Comfortable	5.38 (± 2.01)	4.88 (± 1.90)	1.37	0.18	5.10 (± 1.91)	4.90 (± 1.85)	0.78	0.44	5.85 (± 1.69)	5.18 (± 2.05)	1.74	0.09
Content	5.35 (± 2.15)	4.73 (± 1.81)	2.22	0.03*	4.83 (± 2.10)	4.83 (± 1.85)	0.00	1.00	5.08 (± 2.19)	5.00 (± 2.18)	0.22	0.83
Curious	5.23 (± 2.13)	4.35 (± 2.11)	3.07	< 0.01*	4.10 (± 2.16)	3.93 (± 1.93)	0.91	0.37	5.13 (± 2.21)	4.95 (± 2.28)	0.55	0.58
Disgusted	2.03 (± 1.69)	1.83 (± 1.47)	0.75	0.46	2.13 (± 1.83)	2.30 (± 2.15)	-0.64	0.52	2.43 (± 1.88)	2.45 (± 2.19)	-0.07	0.95
Eager	4.00 (± 1.93)	3.93 (± 2.20)	0.27	0.79	3.80 (± 1.99)	4.08 (± 1.99)	-1.05	0.30	4.18 (± 2.40)	4.05 (± 2.45)	0.40	0.69
Energetic	3.83 (± 2.23)	3.80 (± 1.86)	0.08	0.94	4.63 (± 2.10)	4.83 (± 1.95)	-0.83	0.41	5.10 (± 1.91)	4.98 (± 1.98)	0.43	0.67
Good	5.35 (± 2.02)	5.10 (± 1.61)	0.90	0.37	5.18 (± 2.01)	4.75 (± 1.90)	1.39	0.17	5.80 (± 1.79)	5.33 (± 2.02)	1.38	0.17
Happy	5.40 (± 2.02)	4.73 (± 1.62)	2.61	0.01*	5.00 (± 2.18)	4.75 (± 1.92)	1.01	0.32	5.85 (± 1.87)	5.08 (± 2.13)	2.28	0.03*
Off balance	2.20 (± 1.70)	2.20 (± 1.44)	0.00	1.00	1.83 (± 1.41)	2.00 (± 1.62)	-1.10	0.28	2.10 (± 1.52)	2.33 (± 1.86)	-0.74	0.46
Peaceful	5.40 (± 2.11)	4.68 (± 1.58)	2.39	0.02*	4.88 (± 2.24)	4.70 (± 1.86)	0.74	0.47	5.33 (± 1.86)	4.58 (± 1.96)	2.04	0.05*

Asterisks indicate significant differences between the means of control and the sample cup as determined by paired t-tests at $P < 0.05$.

Table 2. Mean (± standard deviation) of the degrees of intensity of emotional attributes among coffee samples in three treatment groups, i.e., presented with control (cardboard) and one of the three cup sleeve samples (towel, linen, or stainless steel) (Cont.).

	Groups											
	Towel				Linen				Stainless Steel			
	Towel	Control	t	p	Linen	Control	t	p	Stainless Steel	Control	t	p
Pleasant	5.33 (± 2.14)	4.88 (± 1.64)	1.33	0.19	4.93 (± 1.95)	4.60 (± 2.01)	1.22	0.23	5.68 (± 1.91)	5.00 (± 2.10)	1.83	0.08
Pleased	5.33 (± 2.08)	4.33 (± 1.80)	2.84	0.01*	4.83 (± 2.01)	4.50 (± 1.87)	1.28	0.21	5.58 (± 2.05)	4.95 (± 2.33)	1.68	0.10
Relaxed	5.48 (± 2.08)	4.43 (± 1.85)	2.93	0.01*	4.73 (± 1.92)	4.38 (± 1.78)	1.50	0.14	5.28 (± 1.97)	4.95 (± 2.21)	0.92	0.36
Satisfied	5.25 (± 2.10)	4.75 (± 1.85)	1.41	0.17	4.98 (± 2.12)	4.73 (± 1.97)	0.80	0.43	5.23 (± 2.25)	4.78 (± 2.24)	1.10	0.28
Soothing	5.00 (± 2.38)	4.08 (± 1.83)	2.59	0.01*	4.25 (± 2.44)	4.08 (± 1.87)	0.52	0.61	4.60 (± 2.36)	4.15 (± 2.19)	1.19	0.24
Warm	4.85 (± 2.49)	3.78 (± 1.97)	3.74	< 0.01*	5.50 (± 1.68)	5.03 (± 1.80)	2.28	0.03*	5.58 (± 1.88)	5.43 (± 1.93)	0.60	0.55
Wild	1.83 (± 1.50)	2.05 (± 1.55)	-1.46	0.15	2.45 (± 1.81)	2.85 (± 2.14)	-1.50	0.14	2.43 (± 1.62)	2.53 (± 1.65)	-0.40	0.69
Liking	6.45 (± 1.89)	6.03 (± 2.04)	1.31	0.20	5.80 (± 2.24)	5.50 (± 2.29)	0.70	0.49	6.18 (± 2.36)	5.88 (± 2.31)	0.81	0.42

Asterisks indicate significant differences between the means of control and the sample cup as determined by paired t-tests at $P < 0.05$.

Table 3. Mean (± standard deviation) of the degrees of intensity and liking of sensory attributes among coffee samples in three treatment groups, i.e., presented with control (cardboard) and one of the three cup sleeve samples (towel, linen, or stainless steel).

	Groups											
	Towel				Linen				Stainless Steel			
	Towel	Control	t	p	Linen	Control	t	p	Stainless Steel	Control	t	p
Overall aroma L	6.68 (± 1.25)	5.95 (± 1.50)	2.59	0.01*	5.58 (± 1.75)	5.73 (± 1.74)	-0.55	0.58	5.90 (± 1.69)	6.13 (± 1.40)	-0.81	0.42
Overall aroma I	5.90 (± 1.17)	5.48 (± 1.68)	1.53	0.13	5.78 (± 1.27)	5.58 (± 1.48)	0.81	0.42	5.50 (± 1.47)	5.38 (± 1.55)	0.44	0.66
Bitter aroma I	4.45 (± 1.58)	4.88 (± 1.91)	-1.35	0.18	5.13 (± 1.67)	5.30 (± 1.36)	-0.62	0.54	5.00 (± 1.71)	5.08 (± 1.44)	-0.29	0.78
Roasted aroma I	5.73 (± 1.28)	5.65 (± 1.64)	0.23	0.82	5.60 (± 1.37)	5.48 (± 1.54)	0.53	0.60	5.58 (± 1.55)	5.58 (± 1.68)	0.00	1.00
Overall flavor L	6.40 (± 1.74)	5.78 (± 1.93)	1.71	0.09	5.70 (± 2.10)	5.43 (± 2.05)	0.81	0.43	5.55 (± 1.85)	5.28 (± 2.10)	0.85	0.40
Bitter taste I	4.63 (± 1.67)	5.45 (± 1.84)	-3.30	< 0.01*	5.28 (± 1.78)	5.25 (± 1.81)	0.09	0.93	5.33 (± 1.97)	5.35 (± 1.64)	-0.10	0.92
Sweet taste I	3.60 (± 1.97)	3.78 (± 1.89)	-0.66	0.51	3.60 (± 1.88)	3.35 (± 1.69)	1.22	0.23	3.38 (± 1.82)	3.50 (± 1.66)	-0.56	0.58
Sour taste I	4.53 (± 2.03)	4.53 (± 2.11)	0.00	1.00	4.93 (± 2.15)	5.20 (± 2.23)	-1.12	0.27	5.23 (± 1.69)	4.98 (± 2.08)	0.82	0.42
Salty taste I	3.38 (± 1.81)	3.35 (± 1.87)	0.18	0.86	3.95 (± 1.93)	3.85 (± 1.61)	0.37	0.72	4.00 (± 1.81)	4.08 (± 1.95)	-0.04	0.71
Burnt flavor I	4.53 (± 1.63)	4.95 (± 1.87)	-1.19	0.24	4.58 (± 1.87)	4.80 (± 1.81)	-0.74	0.47	4.85 (± 1.89)	5.13 (± 1.87)	-0.90	0.37
Roasted flavor I	5.93 (± 0.971)	5.95 (± 1.38)	-0.13	0.90	5.20 (± 2.00)	5.70 (± 1.59)	-1.87	0.07	5.18 (± 1.66)	5.70 (± 1.47)	-2.16	0.04*
Overall mouth-feel I	6.65 (± 1.33)	6.00 (± 1.47)	2.78	0.01*	5.95 (± 1.68)	5.60 (± 1.77)	1.35	0.19	5.65 (± 1.61)	5.65 (± 1.81)	0.00	1.00
Mouth coating I	5.60 (± 1.41)	5.30 (± 1.22)	1.70	0.10	5.38 (± 1.44)	5.53 (± 1.41)	-0.72	0.47	4.93 (± 1.51)	4.95 (± 1.28)	-0.10	-0.92
Overall L	6.33 (± 1.99)	5.83 (± 1.87)	1.52	0.14	5.90 (± 2.25)	5.50 (± 2.33)	1.11	-0.27	5.55 (± 2.21)	5.35 (± 2.25)	0.72	0.48

"L" and "I" represent "liking" and "intensity", respectively. Asterisks indicate significant differences between the means of control and the sample cup as determined by paired t-tests at $P < 0.05$.

Table 4. Mean (± standard deviation) of the degrees of arousal, valence, and matching of hand-feel of sleeve samples to the coffee samples in three treatment groups, i.e., presented with control (cardboard) and one of the three cup sleeve samples (towel, linen, or stainless steel).

	Groups											
	Towel				Linen				Stainless Steel			
	Towel	Control	t	p	Linen	Control	t	p	Stainless Steel	Control	t	P
Arousal	3.85 (± 2.08)	4.80 (± 1.07)	-2.40	0.02*	4.25 (± 2.31)	4.78 (± 1.33)	-1.37	0.18	4.78 (± 2.14)	4.23 (± 1.59)	1.22	0.23
Valence	6.43 (± 2.22)	4.93 (± 1.82)	2.93	0.01*	7.18 (± 1.45)	4.95 (± 1.95)	5.24	< 0.01*	5.35 (± 2.66)	5.65 (± 1.63)	-0.52	0.61
Matching	5.40 (± 2.22)	5.73 (± 1.65)	-0.87	0.39	6.05 (± 2.36)	5.50 (± 2.29)	1.09	0.28	5.53 (± 2.21)	5.60 (± 2.05)	-0.14	0.89

Asterisks indicate significant differences between the means of control and the sample cup as determined by paired t-tests at $P < 0.05$.

Table 5. Difference of means of the degrees of intensity of emotional attributes among coffee samples in three treatment groups, i.e., presented with control (cardboard) and one of the three cup sleeve samples (towel, linen, or stainless steel).

	Difference of Means				
	Towel	**Linen**	**Stainless Steel**	**F**	**p**
Annoyed	-0.65	-0.45	-0.60	0.09	0.92
Awake	-0.15	0.20	0.13	0.66	0.52
Bored	-0.60_{b}	0.28_{a}	-0.13_{ab}	3.84	0.02
Calm	0.68	0.00	0.28	0.94	0.39
Comfortable	0.50	0.20	0.68	0.50	0.61
Content	0.63	0.00	0.08	1.21	0.30
Curious	0.88	0.18	0.18	2.25	0.11
Disgusted	0.20	-0.18	-0.03	0.37	0.69
Eager	0.08	-0.28	0.13	0.59	0.56
Energetic	0.03	-0.20	0.13	0.35	0.71
Good	0.25	0.43	0.48	0.15	0.87
Happy	0.68	0.25	0.78	0.95	0.39
Off balance	0.00	-0.18	-0.23	0.22	0.81
Peaceful	0.73	0.18	0.75	1.12	0.33
Pleasant	0.45	0.33	0.68	0.29	0.75
Pleased	1.00	0.33	0.63	1.05	0.35
Relaxed	1.05	0.35	0.33	1.65	0.20
Satisfied	0.50	0.25	0.45	0.14	0.87
Soothing	0.93	0.75	0.45	1.12	0.33
Warm	1.08_{a}	0.48_{ab}	0.15_{b}	3.51	0.03
Wild	-0.23	-0.40	-0.10	0.44	0.65
Liking	0.43	0.30	0.30	0.04	0.96

Letters indicate multiple pairwise comparisons results, where values not connected by the same letter are significantly different for each column at $P < 0.05$ as determined by ANOVA.

Table 6. Difference of means of the degrees of intensity of sensory attributes among coffee samples in three treatment groups, i.e., presented with control (cardboard) and one of the three cup sleeve samples (towel, linen, or stainless steel).

	Difference of Means				
	Towel	**Linen**	**Stainless Steel**	**F**	**p**
Overall aroma liking	0.73_{a}	-0.15_{ab}	-0.23_{b}	3.65	0.03
Overall aroma intensity	0.43	0.20	0.13	0.34	0.72
Bitter aroma intensity	-0.43	-0.18	-0.08	0.40	0.67
Roasted aroma intensity	0.08	0.00	0.13	0.05	0.95
Overall flavor liking	0.63	0.28	0.28	0.35	0.71
Bitter taste intensity	-0.83_{a}	0.03_{a}	-0.03_{a}	3.42	0.04
Sweet taste intensity	-0.18	0.25	-0.13	1.00	0.37
Sour taste intensity	0.00	-0.28	0.25	0.91	0.41
Salty taste intensity	0.03	0.10	-0.08	0.18	0.84
Burnt flavor intensity	-0.43	-0.23	-0.28	0.10	0.90
Roasted flavor intensity	-0.03	-0.50	-0.53	1.43	0.24
Overall mouthfeel liking	0.65	0.35	0.00	1.66	0.19
Mouth coating intensity	0.30	-0.15	-0.03	1.20	0.31
Overall liking	0.50	0.40	0.20	0.22	0.80

Letters indicate multiple pairwise comparisons results, where values not connected by the same letter are significantly different for each column at $P < 0.05$ as determined by ANOVA.

Table 7. Difference of means of the degrees of arousal, valence, and matching of hand-feel of sleeve samples to the coffee samples in three treatment groups, i.e., presented with control (cardboard) and one of the three cup sleeve samples (towel, linen, or stainless steel).

	Difference of Means				
	Towel	**Linen**	**Stainless Steel**	**F**	**p**
Arousal	-0.95_{b}	-0.53_{ab}	0.55_{a}	3.53	0.03
Valence	1.50_{a}	2.23_{a}	-0.30_{b}	6.54	0.00
Matching	-0.33	0.55	-0.075	0.92	0.40

Letters indicate multiple pairwise comparisons results, where values not connected by the same letter are significantly different for each column at $P < 0.05$ as determined by ANOVA.

Table 8. Mean sleeve surface temperature (± standard deviation) measured over coffee temperatures of 70 °C to 60 °C, mean sleeve surface temperature measured at 65 °C coffee temperature, and mean time taken for coffee temperature to decrease from 70 °C to 60 °C.

	Mean Sleeve Surface Temperature (°C)	Mean Sleeve Surface Temperature at 65 °C Coffee Temperature (°C)	Mean Time Taken for Coffee Temperature from 70 °C to 60 °C (s)
No sleeve	47.02_a (± 1.26)	47.77_a (± 0.61)	281.00_b (± 11.79)
Cardboard	39.01_b (± 1.42)	39.10_b (± 1.65)	302.00_{ab} (± 9.17)
Linen	35.69_c (± 1.83)	37.03_b (± 0.45)	313.00_{ab} (± 24.58)
Stainless steel	36.89_c (± 2.91)	37.34_b (± 3.24)	308.00_{ab} (± 7.55)
Towel	31.30_d (± 1.20)	31.97_c (± 1.20)	333.67_a (± 2.89)

Subscripts represent a significant difference between the cup sleeve materials at $P < 0.05$.

Table 9. Multivariate correlational relationships between surface temperatures of varying cup sleeves measured at coffee temperature of 60 °C to 70 °C, and degrees of intensities of emotional and sensory terms, and degree of arousal, valence, and matching.

	Surface Temperature	Sa	Sz	Str	Spc	Sdr	Sq	Coefficient of Friction	Max. Deformation
Annoyed	0.90	-0.72	-0.73	0.54	-0.72	-0.75	-0.72	0.21	-0.36
Awake	0.66	-0.85	-0.85	-0.66	-0.79	-0.84	-0.85	-0.86	-0.99
Bored	0.71	-0.51	-0.51	0.47	-0.39	-0.60	-0.51	0.39	-0.28
Calm	-0.52	0.24	0.24	-0.79	0.18	0.31	0.24	-0.79	-0.10
Comfortable	-0.19	-0.11	-0.11	-0.85	-0.17	-0.02	-0.11	-0.89	-0.41
Content	-0.82	0.71	0.70	-0.19	0.56	0.79	0.71	-0.08	0.56
Curious	-0.52	0.34	0.33	-0.36	0.16	0.45	0.34	-0.42	0.21
Disgusted	0.61	-0.82	-0.82	-0.62	-0.83	-0.77	-0.82	-0.90	-0.91
Eager	0.18	-0.35	-0.36	-0.33	-0.53	-0.23	-0.35	-0.67	-0.33
Energetic	0.74	-0.90	-0.90	-0.57	-0.82	-0.90	-0.90	-0.77	-1.00
Good	-0.14	-0.17	-0.17	-0.87	-0.22	-0.09	-0.17	-0.92	-0.48
Happy	-0.29	-0.00	-0.01	-0.82	-0.07	0.08	-0.01	-0.84	-0.31
Off balance	-0.11	0.14	0.12	0.34	-0.10	0.24	0.13	0.05	0.36
Peaceful	-0.72	0.49	0.49	-0.63	0.41	0.56	0.49	-0.47	0.18
Pleasant	-0.32	0.03	0.03	-0.79	-0.05	0.12	0.03	-0.81	-0.26
Pleased	-0.48	0.20	0.20	-0.78	0.13	0.28	0.20	-0.72	-0.13
Relaxed	-0.75	0.55	0.55	-0.50	0.44	0.63	0.55	-0.37	0.29
Satisfied	-0.73	0.48	0.48	-0.70	0.44	0.54	0.48	-0.50	0.12
Soothing	-0.87	0.73	0.72	-0.34	0.62	0.79	0.72	-0.16	0.50
Warm	0.11	-0.35	-0.34	-0.89	-0.19	-0.38	-0.35	-0.74	-0.72
Wild	0.92	-0.92	-0.92	-0.11	-0.81	-0.96	-0.92	-0.32	-0.84

Values in red indicate significant correlations at $P < 0.05$.

Table 9. Multivariate correlational relationships between surface temperatures of varying cup sleeves measured at coffee temperature of 60 °C to 70 °C, and degrees of intensities of emotional and sensory terms, and degree of arousal, valence, and matching (Cont.).

	Surface Temperature	Sa	Sz	Str	Spc	Sdr	Sq	Coefficient of Friction	Max. Deformation
Overall aroma	-0.91	0.94	0.95	0.03	0.99	0.90	0.94	0.47	0.75
Bitter aroma	0.88	-0.86	-0.86	-0.08	-0.73	-0.92	-0.86	-0.24	-0.79
Roasted aroma	-0.96	0.98	0.97	0.11	0.91	1.00	0.98	0.40	0.87
Bitter taste	0.94	-0.95	-0.95	-0.14	-0.86	-0.98	-0.95	-0.38	-0.87
Sweet taste	-0.44	0.67	0.68	0.65	0.73	0.59	0.67	0.93	0.78
Sour taste	0.73	-0.90	-0.89	-0.58	-0.83	-0.89	-0.90	-0.80	-1.00
Salty taste	0.71	-0.84	-0.82	-0.52	-0.69	-0.87	-0.83	-0.61	-0.95
Burnt flavor	0.88	-0.86	-0.87	0.16	-0.95	-0.81	-0.86	-0.31	-0.59
Roasted flavor	-0.35	0.55	0.53	0.78	0.37	0.58	0.54	0.70	0.84
Mouth-coating	-0.69	0.88	0.88	0.56	0.88	0.84	0.88	0.86	0.94
Arousal	0.89	-0.98	-0.98	-0.27	-0.98	-0.95	-0.98	-0.64	-0.90
Valence	-0.59	0.61	0.63	-0.11	0.78	0.52	0.62	0.37	0.37
Matching	0.29	-0.24	-0.22	-0.06	-0.00	-0.35	-0.23	0.16	-0.32

Values in red indicate significant correlations at $P < 0.05$.

Figure Legend

Figure 1. PCA bi-plot based on correspondence analysis illustrating the associations of cup sleeve materials (blue) with emotional responses (red).

Figure 2. Dendogram based on Ward's hierarchical cluster analysis illustrating the classification of cup sleeves based on the degrees of intensity of emotional attributes. Branches above the truncation (red dotted line) indicate significantly different responses between the cup sleeves.

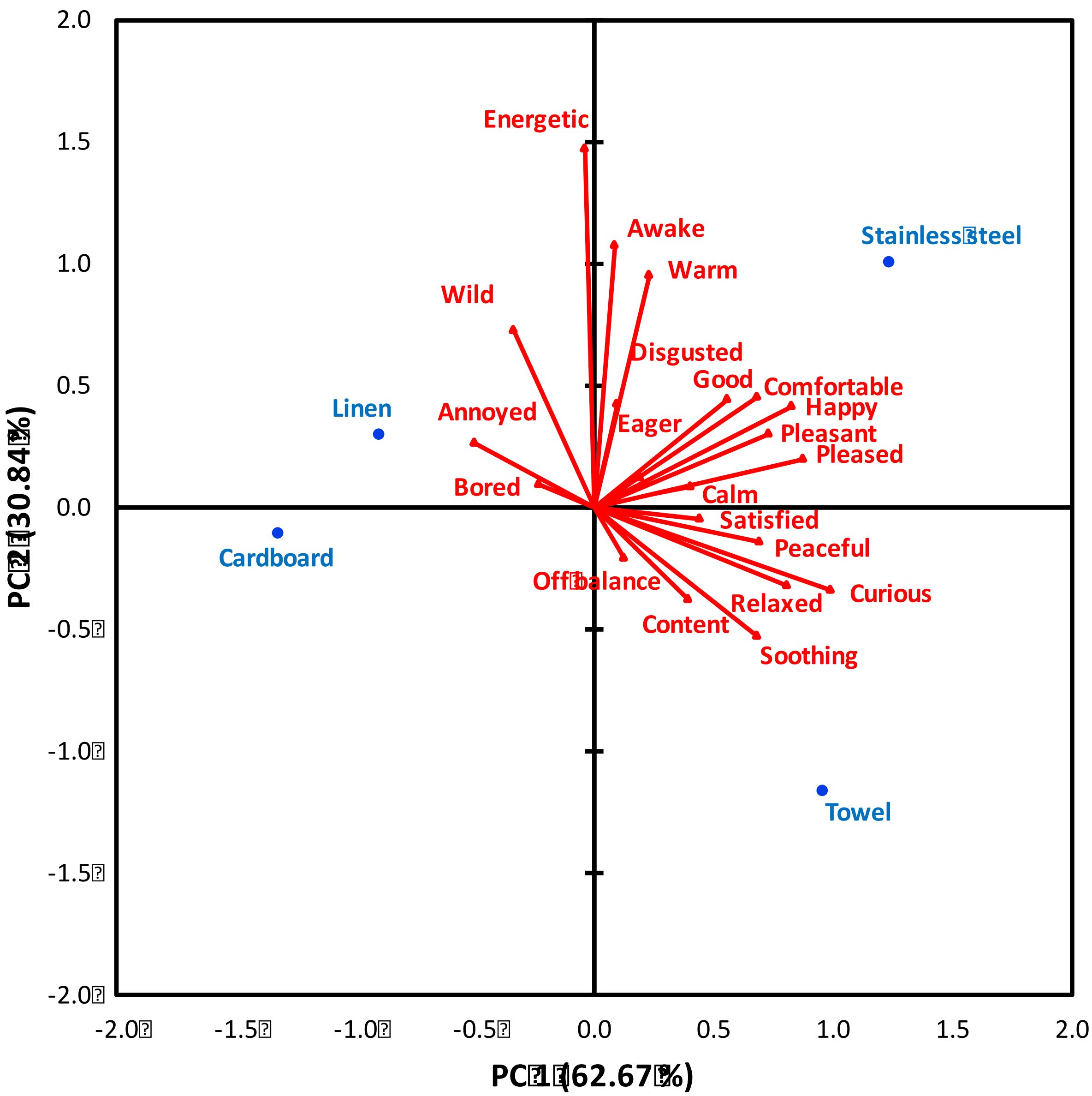
Figure 3. PCA bi-plot based on correspondence analysis illustrating the associations of cup sleeve materials (blue) with sensory attribute ratings (red).

Figure 4. Dendogram based on Ward's hierarchical cluster analysis illustrating the classification of cup sleeves based on the degrees of intensity of sensory attributes. Branches above the truncation (red dotted line) indicate significantly different responses between the cup sleeves.

Figure 5. PCA bi-plot based on correspondence analysis illustrating the associations of cup sleeve materials (blue) with arousal and valence ratings (red).

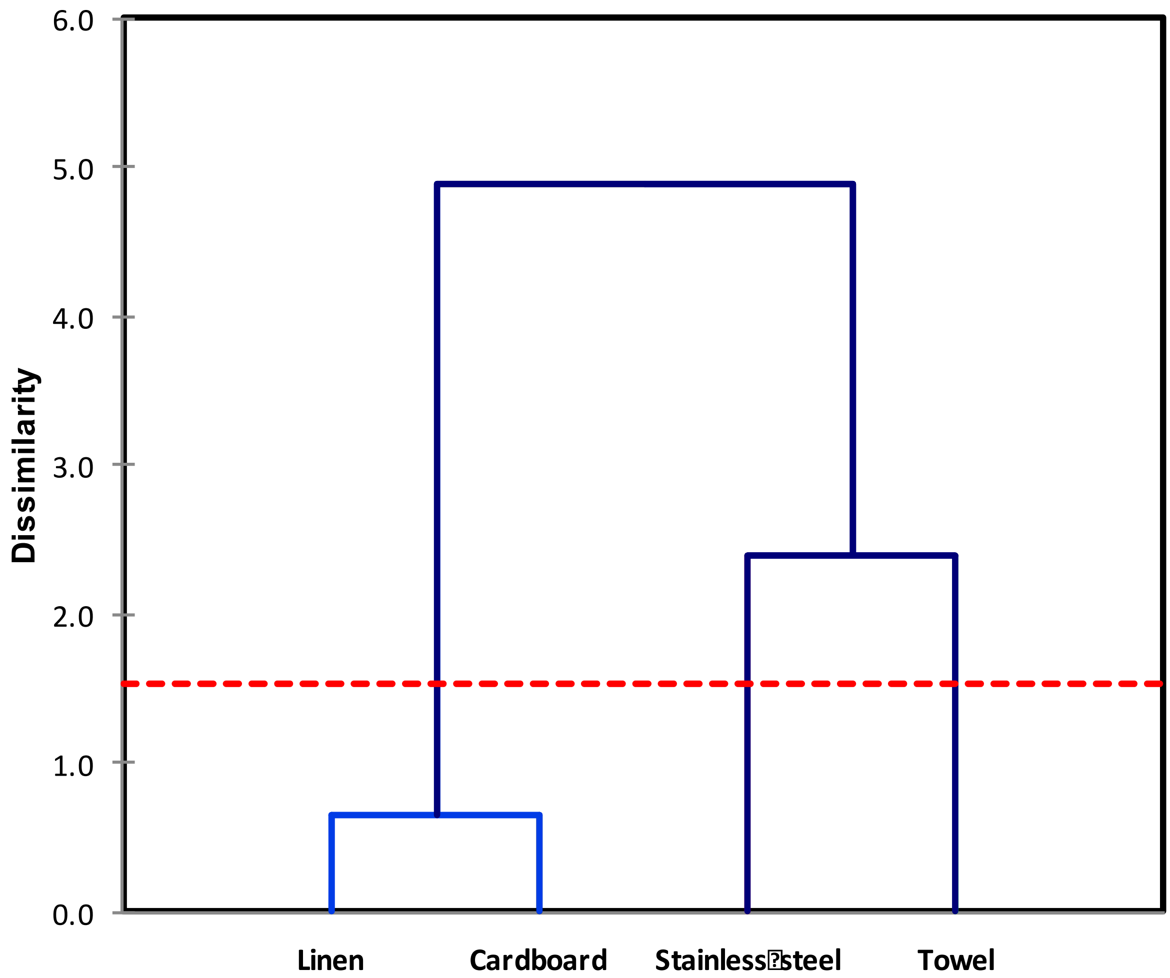
Figure 6. Dendogram based on Ward's hierarchical cluster analysis illustrating the classification of cup sleeves based on the degrees of arousal and valence. Branches above the truncation (red dotted line) indicate significantly different responses between the cup sleeves.

Figure 1.



Energetic
Awake
Warm
Wild
Stainless steel
Disgusted
Good
Comfortable
Happy
Linen
Annoyed
Eager
Pleasant
Pleased
Bored
Calm
Satisfied
Cardboard
Peaceful
Off balance
Curious
Relaxed
Content
Soothing
Towel
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
PC 2 (30.84 %)
PC 1 (62.67 %)

Figure 2.



6.0
5.0
4.0
3.0
2.0
1.0
0.0
Dissimilarity
Linen
Cardboard
Stainless steel
Towel

Figure 3.

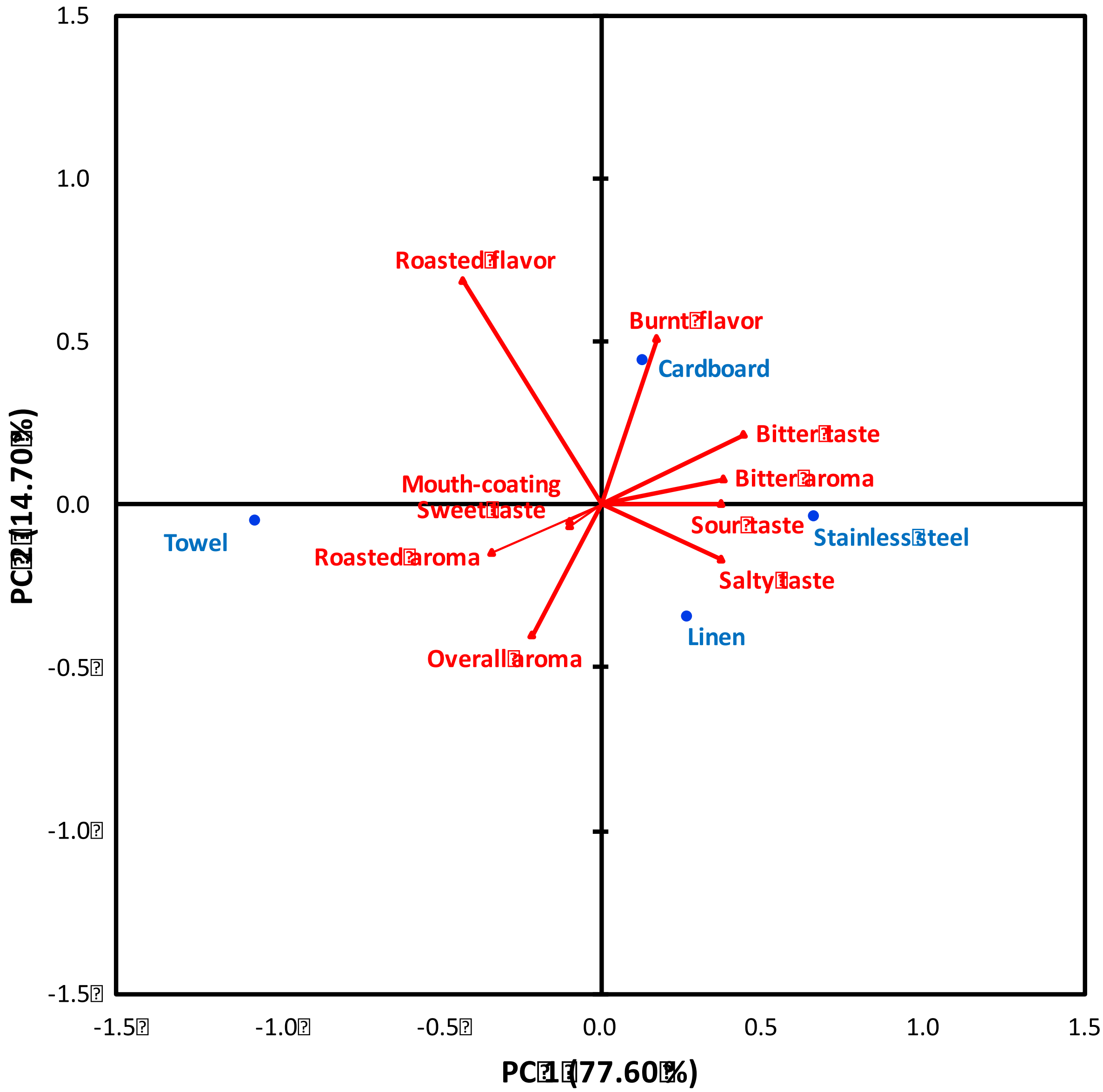
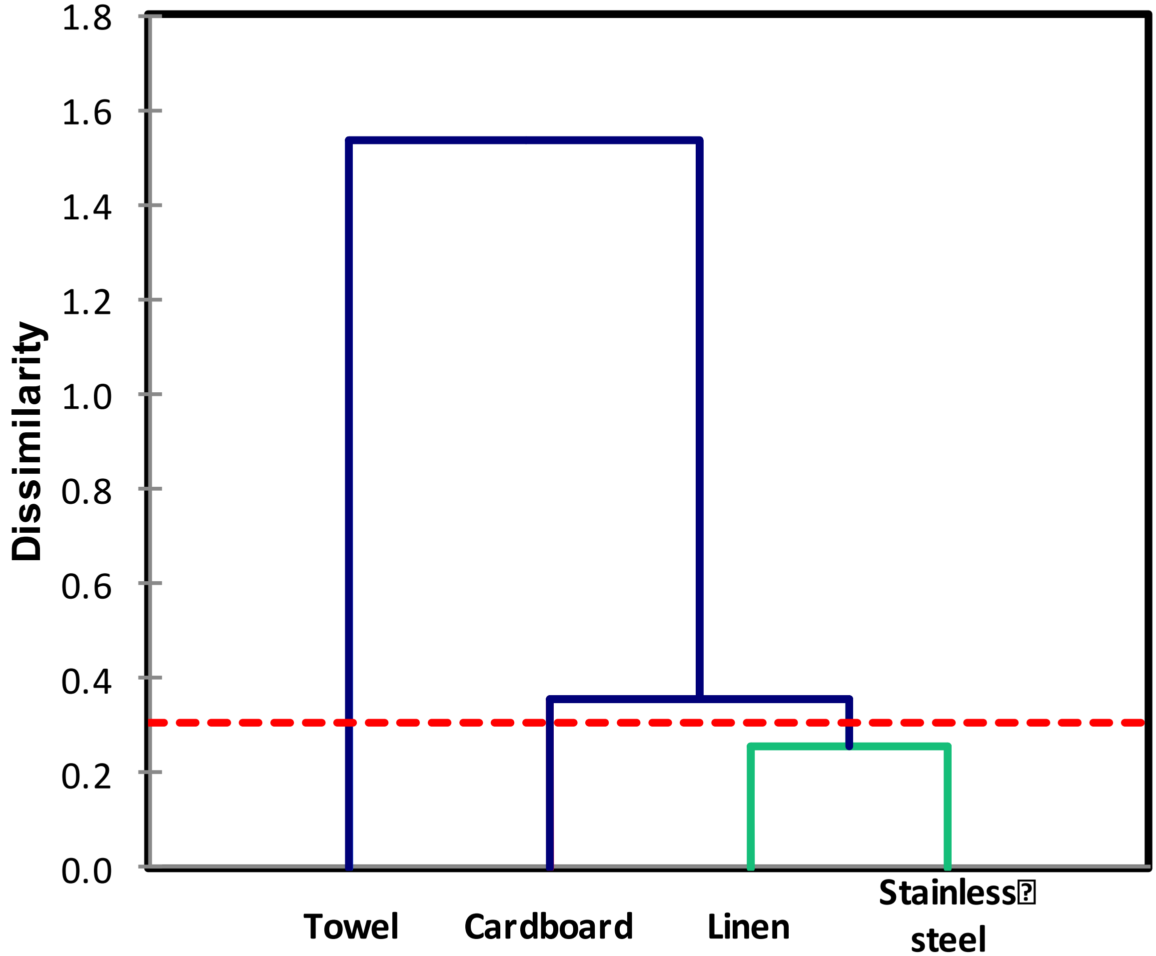

Roasted flavor
Burnt flavor
Cardboard
Bitter taste
Bitter aroma
Mouth-coating
Sweet taste
Towel
Roasted aroma
Sour taste
Stainless steel
Salty taste
Linen
Overall aroma
PC 2 (14.70 %)
PC 1 (77.60 %)
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5

Figure 4.



1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Dissimilarity
Towel
Cardboard
Linen
Stainless steel

Figure 5.

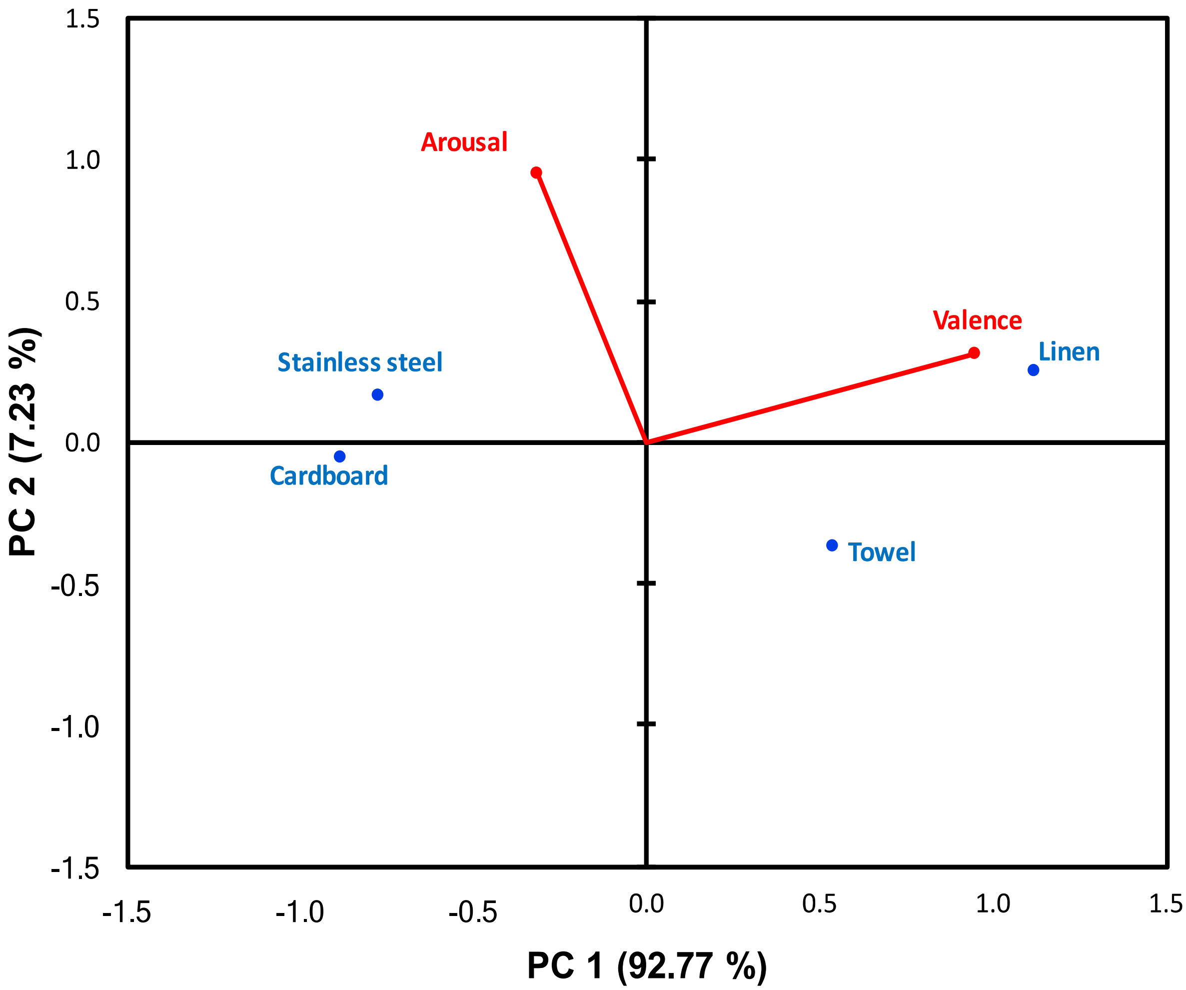
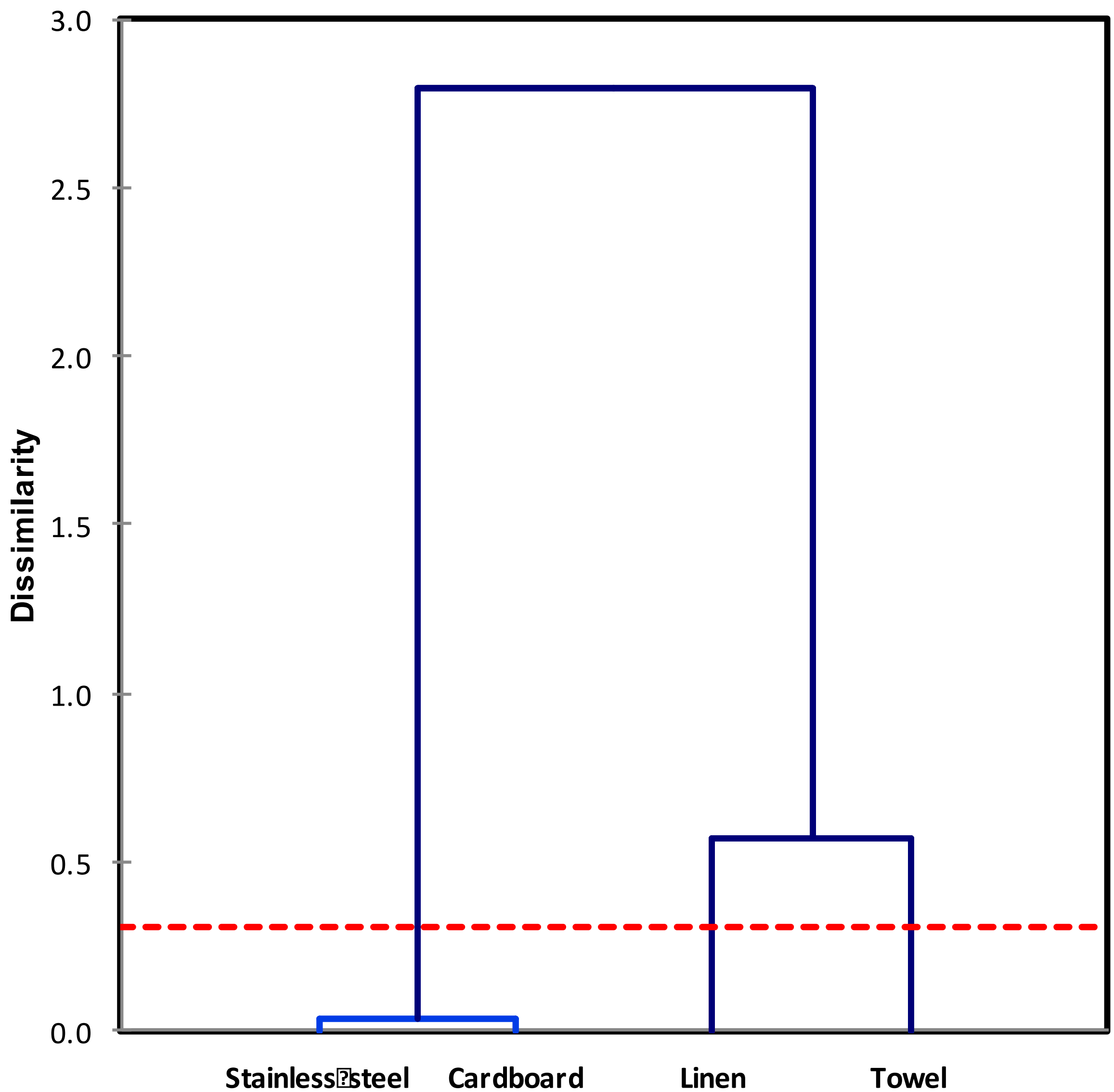

Arousal
Valence
Stainless steel
Linen
Cardboard
Towel
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
PC 2 (7.23 %)
PC 1 (92.77 %)

Figure 6.



3.0
2.5
2.0
1.5
1.0
0.5
0.0
Dissimilarity
Stainless steel
Cardboard
Linen
Towel

CHAPTER 6. Overall Conclusion

In comparing the evoked emotional responses to and sensory perception of only the cup sleeves and brewed coffee presented in the cup sleeves, it was found that the two did not generally mimic the perception of each other as was the case for Schifferstein (2009), although he also noted that some deviations were observed in the study, and largely attributed these deviations to the context effect (Lawless & Heymann, 2010). In the case of Schifferstein (2009), it was posited that the participants might have appraised the cup material from a utilitarian perspective, which coincided with the proposed explanation of the present project, especially **Chapters 4** and **5**. Combining these findings to the remarks by Desmet (2010), in which he postulated that the emotional influence of a product on an individual depends on the way the quality of the material, semantic associations and meanings, and whether its performance matches the expectations of the individual, it would be expected that if a material is deemed to be useful or expected to perform well in the context of the circumstance, it would elicit more positive emotions. The results of the present study was in partial agreement with this hypothesis. Specifically, instrumental measurements and its subsequent correlation analyses to the sensory data indicated that thicker and rougher materials such as towel would be most comfortable to hold a hot beverage with, as confirmed by the high hand-feel liking in **Chapter 4** and the lowest surface temperature when coffee temperature ranged from 60 °C – 70 °C, and showed close associations with positive emotions in both **Chapters 4** and **5**.

Hedonic matching has been frequently mentioned throughout this thesis as part of the complete reasoning behind the cross-modal correspondence effects observed in the present studies. Hedonic matching had been most clearly observed for samples presented with towel sleeves, in which the pleasant hand-feel (shown by the high liking rating of the hand-feel and close associations with positive emotional attributes in **Chapter 4**) matched the high overall liking of brewed coffee in both emotional and sensory attributes in **Chapter 5**, as well as sweet taste the most (in **Chapter 4** and shown by close association to sweet taste in the PCA bi-plot in **Chapter 5**). In addition, from **Chapter 3**, it was also revealed that coffee samples presented at high temperature of 65 °C were described with more positive emotional attributes; some of which were the same as the terms used to characterize towel cup sleeves, e.g., “calm” and “pleased”. Additionally, hedonic matching could also serve as a plausible explanation for stainless steel sleeves, which were found to be most associated with sour taste (**Chapters 4** and **5**), which had been shown in previous studies and in this study (**Chapter 4**) to be affectively both positive and negative. Indeed, when brewed coffee was presented with stainless steel sleeves in **Chapter 5**, coffee was closely associated with both positive and negative emotions.

However, this hedonic matching explanation could not account for the rest of the cup sleeve materials. In particular, cardboard, as the most commercially available material for cup sleeves and thus rated the most familiar and most associated with “bored” and “understanding” feelings in **Chapter 4**, was rated to be most associated with bitter taste and black coffee flavor in **Chapter 4** and illustrated to be closely associated with bitter taste, bitter aroma, and burnt flavor by the PCA bi-plot in **Chapter 5**. Bitter taste solution was rated to be hedonically negative, as shown by liking ratings in **Chapter 4**, and was also found to be a negative driver of liking in brewed coffee in **Chapter 3**, along with burnt flavor. Thus, following the hedonic matching theory, it would be expected that the hand-feel of cardboard would be rated as hedonically negative. Surprisingly, this was not the case, as cardboard was not one of the lowest rated in terms of liking of hand-feel in **Chapter 4**. This was also the case for linen sleeves, which was rated one of the highest in terms of hand-feel liking in **Chapter 4**, and brewed coffee presented with linen sleeves were rated the highest in terms of valence ratings (displayed by difference of means and paired t-test comparisons to cardboard control) in **Chapter 5**. Like cardboard, linen was also closely associated with emotional terms which were hedonically negative such as “annoyed” and “bored” in **Chapter 5**, as well as basic taste quality (salty) rated affectively negative in **Chapters 4** and **5** (PCA bi-plot).

The current proposition to account for the unexplained aspect of the trends observed in this thesis was that familiarity and context effects significantly biased the judgments of the consumers. Fenko et al. (2008) and Ng et al. (2013) showed that humans generally appraise or relate extrinsic aspects of a product to more functional connotations or perspective. Some of the findings of the present study indeed conformed to these proposed concepts. As an example, through instrumental measurements and subsequent correlational analyses, it was found that thicker and rougher materials that offered some protection against the heat and allowed for comfortable grip more positively correlated with positive emotional terms and sweet taste, a hedonically positive taste quality. Therefore, when a consumer deemed a material to possess great utilitarian performance in the appropriate context, they would be more likely to positively appraise a product. Indeed, this proposition largely agreed with the findings of Peck and Childers (2003), in which consumers perceived a product more positively when they were allowed to touch the product for diagnostic purposes, as this increased their confidence in their appraisal. Additionally, Chitturi et al. (2007) discovered that objects deemed functionally superior was preferred more when participants engaged in choice tasks.

Interestingly, while thicker materials, namely towel, were more associated with “warm” feelings in **Chapter 4**, where the participants evaluated the sleeves with basic taste solutions, the same towel material was not closely associated with “warm” in **Chapter 5**, where the participants evaluated the sleeves with brewed coffee. In **Chapter 4**, it was suggested that the “warm” feeling elicited by the towel material was related to the warmth of the pleasant emotions from touching the sleeve materials. Meanwhile, the “warm” feeling in **Chapter 5** was more associated with stainless sleeve, which was established to be thinner, flatter, and provided less protection against the hot coffee beverage (shown by the high surface temperature when coffee temperature ranged between 60 °C – 70 °C). Therefore, in the later chapter, it was posited that the “warm” feeling elicited reflected the actual physical characteristics of the cup sleeve material itself and the physical warmth from the intrinsic product characteristic of a hot beverage. This observation might suggest that when the participants could assess the extrinsic product characteristics in a better contextual environment, i.e., **Chapter 5** with simultaneous presentation of the intrinsic product characteristics of brewed coffee, rather than with just basic taste solutions in **Chapter 4**, the evaluation of the intrinsic aspect of the product, i.e., brewed coffee, would mimic the evaluation of the extrinsic aspect, i.e., cup sleeve material. In other words, it was only in the above example that the present study agreed with the findings of Schifferstein (2009).

Ultimately, the findings of this study provided empirical evidence of cross-modal correspondence between extrinsic and intrinsic product cues, in particular hand-feel touch stimuli via varying cup sleeve materials and sensory characteristics of brewed coffee. To the best of our knowledge, this study was the first to show how cross-modal effects could influence emotional responses evoked from consumer experience in a coffee drinking setting. In addition, this study also pioneered the integration of instrumental parameters and physical characteristics of the extrinsic attributes with cross-modal sensory data and emotional responses in the framework of cross-modality between hand-feel touch and gustatory cues, as majority of the previous studies in this field had only suggested plausible theories. Further, this study was also the first to investigate the dynamics of emotional responses with respect to changing product temperature in brewed coffee and green tea beverages.

With the findings of this thesis, professionals in food and beverage industries should consider several important factors in product development and packaging design:

1. Product temperature. As clearly demonstrated in **Chapter 3**, changes in product temperature could influence consumer sensory perception, evoked emotional responses, and acceptability. As such, professionals should consider at which temperature the consumers will consume the beverage product and should subsequently consider the storage and display temperatures at grocery stores, as well as serving instructions for specific serving temperatures if the product was to exhibit specific sensory properties and evoke specific emotions. In addition, the findings of the present study would also provide for industry professionals a basic reference to predict how brewed coffee and green tea would be perceived emotionally and in terms of their sensory characteristics at different product temperatures.

2. **Packaging/container materials**. Extrinsic product attributes clearly influenced sensory perception and intensities, as well as evoked emotional associations and intensities, of brewed coffee (**Chapter 5**) or the expectation of a brewed coffee (**Chapter 4**) in a coffee drinking scenario. It was apparent that consumers extracted semantic expressions and meanings from their evaluation of the cup sleeves and developed certain expectations of the brewed coffee, supporting the concept of context effect. Context effect, alongside familiarity effect, was shown to strongly influence consumer expectations towards a product, as these biased consumers to appraise the extrinsic aspect of the product in a utilitarian or functional manner in the context of the product being consumed. Therefore, when introducing a novel material or design for a packaging or container, industry professionals must consider how well the extrinsic aspect of a product would perform functionally in the context of the product consumed, in addition to the semantic associations that consumers may already have about the material or design of the packaging or container. Additionally, since familiarity effect also played a role from the findings of the present study, it would also be important to create packaging or container with similar characteristics to those of an already existing or familiar product in the market (Niehoff, 1967). Otherwise, effects such as cognitive dissonance (Festinger, 1957) or assimilation-contrast effect (Anderson, 1973) might be observed, whereby consumers would be greatly dissatisfied when their expectations towards a product were not met by their actual experience with the product.

Overall, the findings of the present project showed that food professionals could manipulate food and beverage consumption experience of consumers through the integration of hand-feel touch cues in packaging or container designs, as well as changing the product temperatures. Since there is currently an increasing trend in using reusable materials due to more awareness of recycling benefits, industry professionals would be advised to consider or invest in finding more means to integrate reusable materials as part of product packaging or container designs. However, successful implementation of these novel packaging or container designs would depend on the consideration of the aforementioned factors and those yet to be studied, e.g., price, willingness-to-pay, appeal, etc. Future research involving hand-feel touch stimuli or packaging/container effects must consider the effects of hedonic matching, context, and familiarity of hand-feel. In addition, further studies on hot food or beverages must consider the impacts of product temperature and must attempt to standardize serving temperatures to minimize variation in sensory perception and evoked emotions in the food or beverage samples.

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Appendices

APPENDIX 1. "Emotional" CATA ballot for sample evaluation based on EsSense.

PANEL # __________
SAMPLE CODE Warm-up

For each sample, please answer the question:
"DOES THE BEVERAGE SAMPLE EVOKE THE FOLLOWING EMOTIONS?"

PLEASE NOTE THAT YOU ARE ALLOWED TO SELECT MULTIPLE EMOTIONS.
(NOT LIMITED TO JUST ONE CHOICE).

Active	□	Glad	□	Pleased	□
Adventurous	□	Good	□	Polite	□
Affectionate	□	Good-natured	□	Quiet	□
Aggressive	□	Guilty	□	Satisfied	□
Bored	□	Happy	□	Secure	□
Calm	□	Interested	□	Steady	□
Daring	□	Joyful	□	Tame	□
Disgusted	□	Loving	□	Tender	□
Eager	□	Merry	□	Understanding	□
Energetic	□	Mild	□	Warm	□
Enthusiastic	□	Nostalgic	□	Whole	□
Free	□	Peaceful	□	Wild	□
Friendly	□	Pleasant	□	Worried	□

APPENDIX 2. Sensory CATA ballot for sample evaluation of coffee.

Panel Name: ______________________ **Sample Number:** ________________

PLEASE CHECK ALL THAT YOU CAN PERCEIVE IN THIS COFFEE SAMPLE.

AROMA (by sniffing)		APPEARANCE		AROMATICS (by tasting)		TASTE (by tasting)		MOUTHFEEL	
Ashy	☐	Cloudy	☐	Ashy	☐	Bitter taste	☐	Astringent	☐
Berry	☐	Oily	☐	Berry	☐	Salty taste	☐	Mouth coating	☐
Bitter aroma	☐	Transparent	☐			Sour taste	☐	Viscous	☐
Brown sugar	☐			Brown sugar	☐	Sweet taste	☐		
Burnt	☐			Burnt	☐				
Cereal	☐			Cereal	☐				
Chemical	☐			Chemical	☐				
Chocolate	☐			Chocolate	☐				
Cocoa	☐			Cocoa	☐				
Fruity	☐			Fruity	☐				
Green/Vegetative	☐			Green/Vegetative	☐				
Metallic	☐			Metallic	☐				
Musty/Earthy	☐			Musty/Earthy	☐				
Nutty	☐			Nutty	☐				
Papery/Cardboard	☐			Papery/Cardboard	☐				
Pungent	☐			Pungent	☐				
Roasted	☐			Roasted	☐				
Skunky	☐			Skunky	☐				
Sour aroma	☐								
Sweet aroma	☐								
Tobacco	☐			Tobacco	☐				

Question) How much do you like or dislike this coffee?

Disike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither dislike nor like	Like Slightly	Like Moderately	Like Very much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐

APPENDIX 3. Sensory CATA ballot for sample evaluation of green tea.

Panel Name: ____________________ **Sample Number:** ________________

PLEASE CHECK ALL THAT YOU CAN PERCEIVE IN THIS GREEN TEA SAMPLE.

AROMA (by sniffing)		APPEARANCE		AROMATICS (by tasting)		TASTE (by tasting)		MOUTHFEEL		AFTERTASTE	
Animalic	☐	Brown	☐	Animalic	☐	Bitter taste	☐	Astringent	☐	Bitter	☐
Ashy	☐	Clear	☐	Ashy	☐	Salty taste	☐	Metallic	☐	Sour	☐
Beany	☐	Green	☐	Beany	☐	Sour taste	☐	Mouth coating	☐		
Bitter/tannic	☐	Sediment	☐			Sweet taste	☐	Smooth	☐		
Burnt	☐	Turbid	☐	Burnt	☐			Viscous	☐		
Chemical	☐	Yellow	☐	Chemical	☐						
Citrus	☐			Citrus	☐						
Earthy/Dirty	☐			Earthy/Dirty	☐						
Fermented	☐			Fermented	☐						
Floral	☐			Floral	☐						
Fruity	☐			Fruity	☐						
Grainy	☐			Grainy	☐						
Grassy/Cut Grass	☐			Grassy/Cut Grass	☐						
Hay-like	☐			Hay-like	☐						
Herbal/Herb-like	☐			Herbal/Herb-like	☐						
Long lasting	☐			Long lasting	☐						
Metallic	☐										
Mild/Mellow	☐			Mild/Mellow	☐						
Nutty	☐			Nutty	☐						
Roasted	☐			Roasted	☐						
Pungent	☐			Pungent	☐						

Question) How much do you like or dislike this green tea?

Disike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither dislike nor like	Like Slightly	Like Moderately	Like Very much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐