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Integration of non-invasive biometrics with sensory analysis techniques to assess acceptability of beer by consumers

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ABSTRACT

Traditional sensory tests rely on conscious and self-reported responses from participants. The integration of non-invasive biometric techniques, such as heart rate, body temperature, brainwaves and facial expressions can gather more information from consumers while tasting a product. The main objectives of this study were i) to assess significant differences between beers for all conscious and unconscious responses, ii) to find significant correlations among the different variables from the conscious and unconscious responses and iii) to develop a model to classify beers according to liking using only the unconscious responses. For this study, an integrated camera system with video and infrared thermal imagery (IRTI), coupled with a novel computer application was used. Videos and IRTI were automatically obtained while tasting nine beers to extract biometrics (heart rate, temperature and facial expressions) using computer vision analysis. Additionally, an EEG mobile headset was used to obtain brainwave signals during beer consumption. Consumers assessed foam, color, aroma, mouthfeel, taste, flavor and overall acceptability of beers using a 9-point hedonic scale with results showing a higher acceptability for beers with higher foamability and lower bitterness. i) There were non-significant differences among beers for the emotional and physiological responses, however, significant differences were found for the cognitive and self-reported responses. ii) Results from principal component analysis explained 65% of total data variability and, along with the covariance matrix ($p < 0.05$), showed that there are correlations between the sensory responses of participants and the biometric data obtained. There was a negative correlation between body temperature and liking of foam height and stability, and a positive correlation between theta signals and bitterness. iii) Artificial neural networks were used to develop three models with high accuracy to classify beers according to level of liking (low and high) of three sensory descriptors: carbonation mouthfeel (82%), flavor (82%) and overall liking (81%). The integration of both sensory and biometric responses for consumer acceptance tests showed to be a reliable tool to be applied to beer tasting to obtain more information from consumers physiology, behavior and cognitive responses.

1. Introduction

Beer is the most popular fermented alcoholic beverage worldwide. It is mainly composed of water, malted barley, hops and yeast. Beer may have additional ingredients such as unmalted cereals (called adjuncts), and flavorings to meet the needs from consumers according to their preference [1]. The quality characteristics of beer based on sensory descriptors are the most relevant factors to focus on to match consumer preference and open new markets. The latter is based on the current trends of consumers demanding higher quality products [2]. The most important components and quality traits from beer are the visual attributes that include foam volume, foam persistence, color, and clarity, as they are related to the first impression that consumers have, which triggers liking responses. Other sensory attributes that determine the acceptability of beer and its quality perception are the alcohol content (which also defines its strength and sweetness level), carbon dioxide (CO_2) content (which determines the visual attributes, mouthfeel and release of aromas), and the absence of off–flavors usually developed in bottled beer [3–5]. Due to the complexity of beer production methods and variations in the different types of the main ingredients (hops, yeast and barley), brewers are able to innovate by modifying beer sensory characteristics to increase beer quality and to suit consumers preferences.

Sensory analysis of beer is the main tool to assess its quality and acceptance among consumers [6]. Sensory evaluation is defined as the science applied to obtain, measure, assess and interpret the reactions of tasters to certain characteristics of food, beverages or other non–food products as they are experienced through the human senses. Although

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there are several tests that help to analyze the sensory characteristics, each of them has different objectives. Within the most used sensory methods, the descriptive and hedonic scale tests are implemented to assess the quality and acceptance of the products, respectively [7,8]. The methods to test liking of products are established and provide data that can be statistically analyzed to interpret the acceptance of consumers for food products, but those measurements are still considered to be subjective, as they are based on intrinsic differences in perception and liking between panelists [7]. There is a growing interest in the development of new and emerging techniques to be applied to sensory science, particularly biometrics, to complement the established procedures and obtain accurate and representative information about the sensory perception of food and beverage products.

Biometrics are different methods used to identify and recognize individuals by their distinctive physiological or behavioral characteristics. Based on this principle, biometric techniques have been widely used for personal authentication for security purposes, such as fingerprinting, face or retina scanners, voice recognition, among others [9]. More recently, research has been focused on biometric applications to obtain responses from the autonomic nervous system (ANS). The ANS is related to the unconscious responses of the human body such as heart rate, body temperature and respiration levels, which are associated to emotional response, arousal and stress [10,11]. Lately, research has been focused on the assessment of emotions elicited by different foods and beverages based on their taste, odor or overall product acceptance. Most of these studies have tested the relationship between the liking of the products using different types of scales and the ANS responses such as facial expressions, heart rate changes (HR), skin conductance and body temperature. However, the methods used for these purposes are highly invasive, since the participants must wear electrodes for skin conductance and temperature on their hands, and on the chest for measuring HR [12–14]. These techniques might not present accurate results, due to the possibility of affecting behavior of tasters such as levels of anxiety by unconscious awareness of the constant monitoring they are being subjected to, due to medium level of invasiveness of sensors.

The measurement of brain activity using the electroencephalogram (EEG) technology has been used mainly as an authentication or identification method [15,16], and to correlate it with emotions using different types of stimuli such as visual and auditory [17,18], and tasting of food or beverages [19,20]. Moreover, early EEG studies considered multiple points of sensors contact with the subject head and forehead or a whole head cap. Furthermore, studies mentioned before did not assess the relationship between brainwave responses and the other biometrics (body temperature, HR and facial expressions), and the conscious liking and just about right (JAR) responses from consumers when tasting food or beverages such as beer.

This paper describes the development of a new method to assess the consumer acceptability of beer, which could be employed for other food and beverages. This study has been based on the assessment of beer liking using a hedonic and just about right (JAR) scales in parallel to non-invasive biometric monitoring methods such as electroencephalograms (EEG), heart rate (HR), facial expressions recognition and body temperature, based on non-contact technology through video analysis algorithms and body temperature based on infrared thermal imagery. This paper describes the use of a new bio-sensory application (App) created for Android Tablet PCs coupled with an integrated camera system to record videos and thermal images of participants. Those videos were analyzed through computer vision analysis algorithms to obtain HR using a customized code written in Matlab® and facial expression recognition using the FaceReader™ software. Additionally, an infrared thermal (IR) camera was used to measure body temperature, which was also analyzed using Matlab®. Finally, brainwaves were tested using a non-invasive headset to obtain the brain activity signals as well as other interpreted responses such as attention, meditation and zone levels. Therefore, this study has the following research questions: RQ1: are there any significant differences between the beers in the conscious and unconscious responses? RQ2: are there any correlations among the variables obtained from the conscious (sensory questionnaire) and the unconscious (biometrics) responses? and RQ3: is it possible to classify the beers according to liking using only the unconscious responses?

Table 1
Types and subtypes of beers considered.

Type	Country of origin	Label	Fermentation
Porter	Poland	Z	Top
Kolsch	Australia	P	Top
Aged Ale	Scotland	IG	Top
Lager	Mexico	XX	Bottom
Lager	Netherlands	H	Bottom
Pilsner	Czech Republic	PU	Bottom
Lambic Cassis	Belgium	LC	Spontaneous
Lambic Framboise	Belgium	LF	Spontaneous
Lambic Kriek	Belgium	LK	Spontaneous

2. Materials and methods

2.1. Beers used in the test

Three brands of beer made using top fermentation production techniques, three from bottom fermentation and three from spontaneous fermentation and from different countries (Table 1) were selected randomly from a set of available commercial products for this study to have a broader range of characteristics and to assess the acceptance of their sensory attributes by consumers.

2.2. Sensory evaluation description

2.2.1. Panelists and beers preparation

To test the integrated biometric and sensory techniques implemented, a sensory session was performed with 30 consumers (19 females and 11 males) between 20 and 55 years old, recruited from the staff and students in The University of Melbourne (UoM) in Australia. Before the tasting session, the participants were asked to read and sign a consent form according to the ethics protocol approved by The University of Melbourne. As part of those ethics consent forms, participants were required to disclose any healthy issues, allergies, alcohol intolerance, among others; therefore, none of the participants suffered from any respiratory, cardiovascular or neurological disorder and, in general, all participants had a moderate physical activity. Participants were asked not to have any food or beverage other that plain water at least 30 mins before the session. Nine beers were covered with aluminum foil by an independent staff member before the sensory sessions to shield the label. A three-digit random number code was assigned to each beer to have double blind testing conditions to reduce biases. The beers were divided into two groups of four and five beers, which were semi-randomized. A sample of 15 mL at refrigeration temperature (4 °C) was provided to participants plus crackers and water to serve as palate cleansers. Participants were instructed to swallow the sample and allowed to rest from 5 to 10 mins between beers to help avoid consumers fatigue due to palate saturation caused by the bitter taste and complex flavors found in beers as well as to the presence of alcohol that would affect the sensorial perception of consumers. This resting time was also used to return to baselines for the biometric measurements. All consumers participated in the session within the same period during the afternoon to avoid the influence of circadian rhythm.

2.2.2. Sensory acceptance tests after testing the product, image and video acquisition (conscious and unconscious responses)

The consumers affective methods consisted of a hedonic and just