Does coffee taste better with latte art? A neuroscientific perspective

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Abstract

Purpose – Visual stimulation affects the taste of food and beverages. This study aimed to understand how latte art affects coffee consumption by collecting participants' brainwave data and their taste responses.

Design/methodology/approach – Seventy subjects participated in a two-stage experiment. Electroencephalography (EEG) was employed to measure brainwave activity. With an interval of one week, each stage involved coffee consumption with and without latte art. The responses to the taste of the coffee were also collected for analysis.

Findings – Significant differences were found in the participants' alpha and beta brainwave bands. When drinking coffee with latte art, the participants' alpha bands were significantly lower, whereas the beta bands were higher. These findings were supported by Bayesian statistics. A significant increase was found in the participants' taste of sweetness and acidity with latte art, and Bayesian statistics confirmed the results for sweetness although the evidence on the increase in acidity was anecdotal. No difference was found in the taste of bitterness.

Originality/value – This study highlights the effect of latte art on coffee consumption. The authors analysed the empirical evidence from this two-stage experimental study in the form of the participants' brainwave data and their responses to taste. This study's original contribution is that it explored the crossmodal effects of latte art on consumers' taste of coffee from a neuroscientific perspective. The results of this study can provide empirical evidence on how to effectively use latte art in practical business environments.

Keywords Brainwave, Crossmodal effect, Latte art, Bayesian statistics, Electroencephalography (EEG)

Paper type Research paper

1. Introduction

Coffee is one of the most popular beverages worldwide (Casalegno *et al.*, 2020; Himawan and Rahadi, 2020; Samoggia and Riedel, 2018), and approximately 400 billion cups are consumed annually (Spence and Carvalho, 2020). The coffee industry is an important part of the global economy, considering that coffee is the second most-traded commodity worldwide (Hsu and Hung, 2005; Ida and Münchow, 2016; Liu *et al.*, 2019). Coffee production in developing countries accounts for over 90% of the world's total coffee production, bringing income to 25 m farmers (Garcia-Freites *et al.*, 2019). According to the statistics of the International Coffee Organization, the total consumption of coffee has increased by 2.2% from 2016/2017 to 2019/2020 (International Coffee Organization, ICO, 2020), which indicates that the global demand for coffee continues to increase. In particular, Taiwanese enjoy drinking coffee every day; this has resulted in the growth of the coffee market in Taiwan (Hung, 2012; Wu, 2017). In addition, the data released by the International Coffee Council (ICC) in 2018 confirmed that Taiwan is one of the countries/regions that lead the world in consumption of fresh coffee. Statistics from

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the Ministry of Finance (2019) show that the volume of coffee imported into Taiwan in the past decade has grown from 9,761,243 kg in 1997 to 29,093,329 kg in 2018, an increase of nearly 200%. Taiwanese drink over 2.85bn cups of coffee annually, which generates revenue of 18.8bn New Taiwan Dollars (around 630m USD) (Liu *et al.*, 2019). Although the coffee market in Taiwan started and developed after the ones in Europe and the United States, coffee consumption has grown rapidly in recent years. Coffee competition has increased with the entry of Starbucks and other international coffee chains into the Taiwanese market (Wu, 2017).

Among the many espresso drinks, the most popular in Taiwan is "coffee latte" (Ho, 2012). Chain cafes, supermarkets and independently operated cafes are constantly launching many new flavours of fancy coffee, but over 45% of the consumers still prefer coffee latte. Coffee latte is a shortened form of the Italian "caffè latte" or "caffellatte", and it literally means "milk coffee" in English (Ilao *et al.*, 2017). Coe and Yeung (2019) pointed out that the new wave of coffee will attract consumers more to high-quality coffee instead of the large-scale consumption patterns of the past. People will focus more on enjoying coffee, rather than simply drinking it. In other words, consumers no longer just eat for the sake of satiety and the physiological needs of calorie intake, but pursue a higher level of spiritual feelings and expectations (Duerlund *et al.*, 2019).

The presentation of latte art on milk-based coffee has been recently considered appealing to consumers (Van Doorn *et al.*, 2015). This kind of art on coffee appeals to baristas around the world and has resulted in global competitions such as World Latte Arts Championship. Briefly, coffee latte is currently being a mainstream among international coffee products, and the drawing pattern on a cup of coffee latte is its unique artistic expression (Chang and McGonigle, 2020). Latte art is created by a barista's drawing technique which involves the pouring of milk over an espresso through technical shaking; this produces a difference in the appearance of the coffee latte because of an artistic design or pattern made with the foam (Tamang, 2017). Despite its popularity in the coffee business, academic exploration on how latte arts affect consumers' tastes remains limited (Van Doorn *et al.*, 2015). Thus, this study aimed to bridge this academic gap.

In the same vein, this study extends our current understanding of neural responses to latte art while drinking coffee because real feedback and responses are difficult to detect by simply observing facial expressions and behaviours (Ismail *et al.*, 2016). Using electroencephalography (EEG) to measure neuronal activity in the brain brings objective value to clinical diagnosis, and this analysis is considered a powerful technique for exploring brain activity oscillations (Hsu and Chen, 2020; Michel and Brunet, 2019). In addition, the use of EEG to detect the brain activity status of subjects poses few technical challenges and is not expensive (Asano and Mitsukura, 2017; Marina and Sofya, 2020; Nilashi *et al.*, 2020). Therefore, this study aimed to detect or identify the participants' brain activities through brainwave physiological signals, which could eventually gauge their genuine reaction about the presence and absence of latte art while drinking coffee.

2. Literature review

2.1 Coffee and latte art

Studies have found that the arousal caused by drinking coffee may come not only from physiological processes but also from psychological processes (Chan and Maglio, 2019). It is a good opportunity to create a place for people to enjoy coffee because the demand is high, and drinking coffee is the lifestyle adopted by all generations (Setiyorini, 2019). Coffee can be presented and consumed in various ways: the taste, aroma and composition of coffee brewing depend on the method of preparation (Niseteo *et al.*, 2012). Although tasting coffee is just a straightforward process, adding coffee latte art to coffee drinks will allow customers to feel

relaxed and improve their preferences and sense of value for the product. Studies have shown that people are willing to pay 11%–13% more for coffee latte (Van Doorn *et al.*, 2015). Thus, after experiencing the second wave of coffee revolution that improved the quality and attributes of coffee (Davids, 2013; Ponte, 2002) , the global coffee market is now undergoing a third wave of transformation, towards a handmade quality method (Folmer, 2014; Howell, 2013; Rosenberg *et al.*, 2018). The main appeal of foamed beverage products lies in their milky frothy top (Deotale *et al.*, 2020) because along with its strong aroma, it also contributes to the visual effect of the beverage, especially during the preparation of coffee latte (Nunes and Coimbra, 1998). The appearance and sensory taste of milk-based coffee greatly depend on foamed milk and the art created upon its surface (Hatakeyama *et al.*, 2019). This study utilised a portable brainwave instrument, along with a coffee latte sensory evaluation survey of the participants, to analyse customer preferences for coffee with and without latte art.

2.2 Sensory evaluation and its neuroscientific rationale

Sensory quality is acknowledged as an important aspect of consumers' concepts about the quality of food and beverages (Giacalone *et al.*, 2016). Most people recognise five basic flavours: bitter, sweet, sour, salty and umami (Liman *et al.*, 2014). Taste is sensed by the receptor cells arranged on the taste buds, which are not mainly present on the tongue but also in other parts of the mouth. These taste receptor cells are constantly renewed every 7–10 days (Scott and Plata-Salamán, 1999). The sensory evaluation of food and beverages is transmitted by brain nerves, which carry the tactile, temperature and pain-sensitive information from the tongue to the main taste cortex through the thalamus of the brain (Pritchard *et al.*, 1989). Neuroimaging studies have determined that food intake is regulated by the neural mechanism in the brain (i.e. the basic cognitive and emotional processes in the brain and the orbitofrontal cortex, which is the main area linking food and hedonic experience) (Barrós-Loscertales *et al.*, 2012; Kringelbach, 2004; Piqueras-Fiszman and Spence, 2015). More neuroscientific evidence shows that after food image stimulation, food cravings are related to the activation of the hippocampus and insula in the brain (De Pauw *et al.*, 2017), reflecting the region's involvement in food memory, hippocampal gyrus activation and cravings for food cues (Wallner-Liebmann *et al.*, 2010).

Previous sensory studies had employed self-reported surveys or focus group interviews to perform sensory evaluation of a particular item (Lagast *et al.*, 2017). Newly developed methods using physiological and neural responses (such as EEG) have been widely used by many researchers (Andersen *et al.*, 2019; Chenghu *et al.*, 2019; Ding *et al.*, 2020; Horska *et al.*, 2016; Hsu and Chen, 2019; Toepel *et al.*, 2015; van Bochove *et al.*, 2016; Viejo *et al.*, 2019). For example, Kim and Kim (2015) investigated the correlation analysis of brain waves and evaluated taste by using brain waves to analyse the content of sensory evaluation of taste. The overall results of the differences between the brain waves showed that the sweet, salty and bitter tastes could be detected by EEG, which is consistent with the findings reported by Kotini *et al.* (2016). Taste stimuli trigger neural activities in the cerebral cortex (Hashida *et al.*, 2005; Walsh *et al.*, 2017). The most commonly used bands in the EEG power spectrum are delta waves (0.5–4 Hz, which can be detected during deep sleep), theta waves (4–8 Hz, which can be detected in children and during light sleep), alpha waves (8–13 Hz, which can be detected in an awake, but relaxed person), beta waves (13–30 Hz, which can be detected in an alert, conscious or excited person) and gamma waves (>30 Hz, representing learning, memory and language processing and disappears during anaesthesia and deep sleep) (Ismail *et al.*, 2016; Songsamoe *et al.*, 2019; Subha *et al.*, 2010; van Bochove *et al.*, 2016).

Although studies have addressed sensory evaluation from a neuroscientific perspective, to the best of our knowledge, there is no information as to whether consumers' brainwaves would be affected by the presence of latte art.

2.3 Crossmodal correspondence between visual stimuli and taste

Crossmodal correspondence has attracted extensive attention in enhancing consumer experience (de Sousa *et al.*, 2020; Heatherly *et al.*, 2019; Peng-Li *et al.*, 2020; Piqueras-Fiszman and Spence, 2015; Pramudya *et al.*, 2020; Spence and Carvalho, 2019). Although studies have been conducted to explore the relationship between visual stimuli of food and their taste, they have mostly focused on the shape (Turoman *et al.*, 2018) or colour (Piqueras-Fiszman and Spence, 2012). For example, round shapes seem to suggest a sweet taste, whereas angular shapes suggest a bitter taste (Heatherly *et al.*, 2019; Wang and Spence, 2018). The identification and selection of food or beverages is usually based on their appearance because visual stimuli can prompt people to recall their past food intake experiences (Christoffersen *et al.*, 2017). Attention drawn to sensory attributes of priming stimuli is considered to eventually change the perception towards the target item (Spence, 2012). Our knowledge about the effects of the presentation of latte art on consumers' taste of coffee is still limited. Therefore, to bridge this gap, this study provides insights on this issue.

3. Methods

3.1 Research hypothesis

Based on the aim of this study and with reference to pertinent literature, two research hypotheses were proposed for further analysis:

H1. Five brainwave oscillations are different in coffee drinkers when they are drinking coffee with and without latte art.

H2. Consumers' taste of coffee (bitterness, acidity and sweetness) will be different with and without latte art.

3.2 Participants

Participants in this present study were recruited through various social media platforms or by word of mouth. The pilot study had 30 participants (15 males and 15 females; age range: 18–24 years, mean (M) = 21.6, (SD) = 2.1), and the formal experiment had 70 participants (28 males and 42 females; age range: 28–45 years, M = 31.3, SD = 5.4). The participants were invited to drink milk-based coffee, with and without latte art, and their brainwave oscillations were measured simultaneously. After drinking the coffee, the participants had to rate their feedback based on the taste attributes (i.e. sweetness, bitterness, and acidity) of the coffee on a five-point Likert scale (1 = not at all; 2 = a little bit; 3 = neutral; 4 = much so; 5 = very much so).

Based on the previous study of Hsu and Chen (2019), the participants recruited for this study were not familiar with EEG or other neuroscience-related experimental programmes. They did not have brain-related diseases, hearing impairment, food allergies or caffeine addiction, and they did not use drugs that affected their sense of taste. Moreover, the participants were regular coffee consumers who had received no coffee sensory evaluation training, had no professional knowledge of coffee and were not familiar with latte art techniques. To reduce the noise that may affect the accuracy of the EEG signals, participants were asked to minimise their physical activity during the experiment, breathe as deeply as possible and maintain a comfortable, relaxed and calm mood (Thammasan *et al.*, 2017). Before and after tasting coffee, the participants were asked to drink filtered natural still water at room temperature (25 degree Celsius) to rinse their mouth and reduce the consumption of factors such as the taste of food or drink the participants just consumed that could cause taste sensory interference.

3.3 Research procedure and stimuli

We started with a pilot study to examine whether the complexity of latte art could affect consumers' taste. A repeated-measure experiment was subsequently designed in which the

independent variable was the presence (vs. no presence) of latte art. The same group of participants were involved in this two-stage experiment and were informed about the aim of this study, that is, to examine their taste of coffees. They were asked to visit the research site twice with an interval of one week to reduce any possible bias caused by their memory. The research site was the same café of a five-star hotel, and as its surroundings were quiet and comfortable, and less interference during the experiment could be ensured. In addition, the consumers could focus more on "tasting"the coffee and not get distracted due to other reasons (e.g. the surrounding noise), which might affect the main aim of this experiment. Before the onset of the experiment, all participants were informed about the nature and detailed procedure of this study, and their written consent was obtained.

Two cups of milk-based coffee made with blended beans were presented to all participants. One had latte art, and the other did not. The same barista made every cup of coffee. Each cup of coffee was made using a La Pavoni BAR-T 2V-R espresso machine set to "regular" taste to ensure that all variables, such as temperature and taste of each cup of coffee, were identical to each other (two cups of milk-based coffee are presented in Plate 1). Moreover, the temperature (25.5 °C) and the lighting (350 LUX) in the experimental site were kept constant. All participants drank two cups of coffee latte, and the only difference between these two cups was the presentation of latte art. Before drinking the coffee, the participants were instructed to rinse their mouths with filtered natural still water to exclude any possible influence prior to tasting.

3.4 Apparatus

The participants were provided with ~250 mL of coffee latte (two shots of ~25 mL espresso and ~200 mL of full-cream milk with froth) served in a white, porcelain mug (Plate 1). The containers used in this study were identical, as containers have been found to affect the sensory perception of the consumers (Van Doorn *et al.*, 2014). In addition, the participants were not allowed to add sugar or sweetener to their coffee, to ensure the reliability of all the experimental stimuli. For brainwave data collection, this study used NeuroSky as the non-invasive instrument: one dry electrode sensor was placed on the participants' left forehead (frontal lobe), and the earlobes are clamped. The perturbation signals were filtered, while effective signals were amplified and converted by bluetooth transmission into the system that provides the output as a parameter through a NeuroSkyeSense™ patented algorithm to interpret the participants' brainwave oscillations. Berthoud and Morrison (2008) pointed out that humans recognise food and evaluate the taste mainly through activation of the prefrontal cortex of the brain; hence, it is plausible to use NeuroSky to collect participants' brainwave data for this study. In addition, NeuroSky has been used extensively by previous empirical studies (Hsu, 2020; Hsu and Chen, 2019; Lin and Kao, 2018; Srimaharaj *et al.*, 2018).

Plate 1.
Coffee with and without latte art

3.5 Data analysis

For statistical analysis, this study used paired-samples *t*-test to determine whether the independent variable (i.e. with/without latte art) created a significant difference in the dependent variables (participants' five brainwave bands and three sensory tastes). The significance level of the *t*-test was set at $p < 0.05$, and effect sizes (Cohen's *d*) were reported if the result was significant. Other than traditional frequentist statistics (i.e. *p*-value and null hypothesis), Bayesian statistics were also adopted to complement the data (Beard *et al.*, 2016; van de Schoot *et al.*, 2017). In this study, frequentist statistical analyses were performed using SPSS version 22.0, whereas R 3.6 was used for Bayesian statistics.

3.6 Pilot study

The pilot study was conducted at the same venue where the formal study had been performed, but a different group of participants ($n = 30$) was recruited. The purpose of the pilot study was to determine whether the type of latte art could affect the participants' sense of aesthetics. According to Turoman *et al.* (2018), participants reported that their taste of food is affected by the perceived aesthetics of the shape of the food. We designed and conducted a pilot study to exclude this variable (the shape and complexity of latte art) from the study so that our results could focus on the presence (vs absence) of latte art. Therefore, the independent variable in our pilot study was the shape and complexity of the latte art (Plate 2), whereas the dependent variable was the taste of the coffee.

Thirty participants were enrolled in this pilot study. They participated in the experiment voluntarily, and they got two cups of coffee, free of cost. The results indicated that participants' tastes (bitterness, acidity and sweetness) were not significantly different when latte arts of different complexity were presented ($t_{\text{Bitterness}} = 1.17$, $p > 0.05$; $t_{\text{Acidity}} = 1.11$, $p > 0.05$; $t_{\text{Sweetness}} = 0.22$, $p > 0.05$). Such results indicated that the different shapes of latte art did not significantly affect the taste perception of most people with respect to coffee, which also justified the focus of this study on the presentation of latte art.

4. Results

After completing the pilot study, two rounds of the main experiment were conducted, and the data were collected and analysed.

4.1 Brainwave with/without latte art

To determine whether the presence of latte art could affect five brainwave power bands, a paired-sample *t*-test was administered (Table 1).

Among the five brainwave bands measured, two brainwaves (alpha and beta bands) were significantly different when drinking coffee with and without latte art ($t_{\text{Alpha}} = 4.97$, $t_{\text{Beta}} = -5.39$, $p = 0.00$). The alpha brainwave was significantly higher when the

Plate 2.
Latte arts of the pilot study

Brainwave	Latte art	*M*	Mean difference	SD	*t*	Cohen's *d*	Bayes Factor
Delta	No	20.35	0.78	3.86	1.69	0.20	1.99 (in favour of H0)
	Yes	19.57					
Theta	No	10.23	−0.33	1.88	−1.46	0.15	2.77 (in favour of H0)
	Yes	10.56					
Alpha	No	25.47	2.62	4.41	4.97***	0.69	72.95 (in favour of H1)
	Yes	22.85					
Beta	No	22.99	−2.51	3.90	−5.39***	0.62	16346.32 (in favour of H1)
	Yes	25.50					
Gamma	No	20.96	−0.56	3.95	−1.19	0.16	3.88 (in favour of H0)
	Yes	21.51					

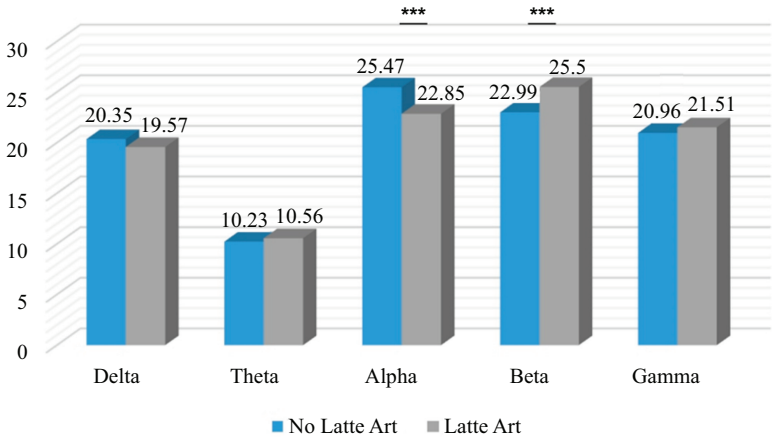
Note(s): ***$p < 0.001$
According to Jeffreys' (1961) Bayes factor cut-off, BF > 100 indicates extremely strong evidence; 3 < BF < 10 indicates moderate evidence; BF = 1 indicates that the data do not favour either hypothesis more than the other

Table 1.
Paired-sample *t*-test comparisons between five of the participants' brainwaves when drinking coffee with and without latte art

participants drank coffee without latte art (vs with latte art), whereas their beta brainwave was significantly higher when they drank coffee with latte art. The effect size also indicates that the magnitude of the experimental effect of these two brainwaves was slightly above medium (Cohen's $d = 0.69$ for alpha and Cohen's $d = 0.62$ for beta bands, respectively) (Cohen, 1988). Moreover, the results of frequentist statistical analyses were confirmed by Bayesian statistics; namely, BF = 72.95 for alpha and BF = 16,346.32 for beta, both of which represent strong evidence in favour of the alternate hypothesis H01. In addition, the participants' gamma bands were not significant in the *t*-test, while Bayesian statistics (BF = 3.88) showed only moderate evidence in favour of the null hypothesis. The results of paired-sample *t*-test comparisons between five brainwaves are shown in Figure 1.

4.2 Taste of coffee with/without latte art

To test the second research hypothesis, a series of paired-sample *t*-tests were performed to examine whether the participants' taste of coffee (bitterness, acidity and sweetness) were affected by the presence (vs. no presence) of latte art (Table 2).



Note(s): ***$p < 0.001$

Figure 1.
Paired-sample *t*-test comparisons between five brainwaves of the participants

The results of the *t*-tests showed that the participants' tastes of acidity and sweetness of coffee were significantly different when the coffee was decorated with latte art (vs no latte art) ($t_{Acidity} = -2.52, p < 0.05$; $t_{Sweetness} = -4.11, p < 0.001$); however, no significant difference was found in the taste of bitterness. Sweetness had a medium effect size (Cohen's $d = 0.60$), whereas acidity had a small effect size (Cohen's $d = 0.37$). Bayesian statistics revealed that the evidence of the participants' taste of sweetness being different when drinking coffee with latte art was decisive (BF = 194.41), whereas the evidence of the taste of bitterness being different for coffee with latte art was substantial (BF = 5.03). Although the taste of acidity was significantly different by frequentist statistical analysis, such a difference was considered anecdotal (BF = 2.46). Thus, we concluded that consumers tasted the coffee to be sweeter with latte art (vs no latte art). The results of paired-sample *t*-test comparisons between the participants' taste of bitterness, acidity and sweetness are shown in Figure 2.

5. Discussion, limitations and implications

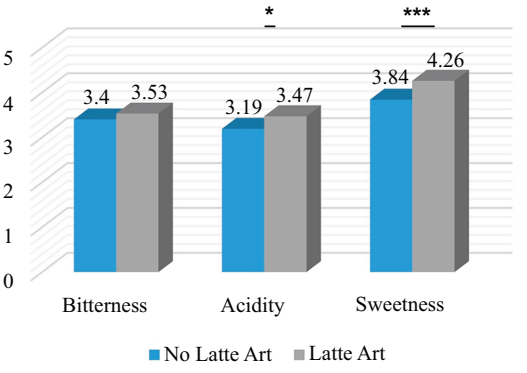
5.1 Discussion

This study explored the hypothesis that consumers' brainwave oscillations as well as their tastes of bitterness, acidity and sweetness of coffee was notably different with and without the presence of latte art. Our pilot study indicated that the complexity of latte art did not affect

Brainwave	Latte art	*M*	Mean difference	SD	*t*	Cohen's *d*	Bayes Factor
Bitterness	No	3.40	−0.13	1.13	−0.95	0.16	5.03 (in favour of H0)
	Yes	3.53					
Acidity	No	3.19	−0.29	0.95	−2.52*	0.37	2.46 (in favour of H1)
	Yes	3.47					
Sweetness	No	3.84	−0.41	0.84	−4.11***	0.60	194.41 (in favour of H1)
	Yes	4.26					

Note(s): *$p < 0.05$, ***$p < 0.001$
1. The participants had to rate their feedback on the attributes of the coffee on 5-point Likert scales (1 = not at all, 2 = a little bit, 3 = neutral, 4 = much so, 5 = very much so)
2. According to Jeffreys' (1961) Bayes factor cut-offs, BF > 100 indicates extremely strong evidence; 3 < BF < 10 indicates moderate evidence

Table 2.
Paired sample *t*-test comparisons between participants' tastes when drinking coffee with and without latte art



Note(s): *$p < 0.05$, ***$p < 0.001$

Figure 2.
Results of paired sample *t*-test comparisons between participants' taste of bitterness, acidity, and sweetness on 5-point likert scales (1 = not at all, 2 = a little bit, 3 = neutral, 4 = much so, 5 = very much so)

consumers' taste of bitterness, acidity and sweetness of coffee. These findings differ from those reported by Spence and Van Doorn (2017), in which consumers rate coffee with round latte art (vs angular latte art) as high quality and believe that angular latte art would make the coffee taste bitter. However, the present study revealed that the presence of latte art had some influence on the participants' neural activities in the brain; specifically, among the five brainwave power bands examined, alpha and beta bands were significantly different. The results of the present study were in agreement with those of previous studies in two aspects. First, our results agreed with the opinion of Bernardi *et al.* (2019), Nguyen *et al.* (2017), Hsu and Chen (2019) and Zhong (2015), who proposed that delta and theta waves cannot be activated when an individual is fully awake. Our results were also consistent with the conclusions of De Pauw *et al.* (2017), Labbe *et al.* (2011) and Murao *et al.* (2013), that the taste of food would trigger the alpha and beta brainwaves. Moreover, the study by Van Boshove *et al.* (2016) indicated that one's alpha and beta bands were related to a hedonic attitude towards food and affected one's food preference. Specifically, in this study, when the participants were drinking coffee without latte art, their alpha brainwaves were significantly higher than when they were drinking coffee with latte art, whereas when the participants were drinking coffee with latte art, their beta brainwaves were significantly higher than when they were drinking coffee without latte art. Alpha brainwaves indicate that the body and mind are in a state of relaxation, whereas beta brainwaves indicate states of alertness and concentration (Campbell, 2009; Ismail *et al.*, 2016; Takahashi *et al.*, 2005; Songsamoe *et al.*, 2019; Subha *et al.*, 2010; van Bochove *et al.*, 2016). It has been postulated that drinking coffee with latte art will enhance one's alertness; in contrast, drinking coffee without latte art would make one relax and increase the alpha brainwave (Van Diepen *et al.*, 2019). From the perspective of visual senses, this result is in agreement with the findings of Van Diepen *et al.* (2019), where a higher alpha brainwave actually represents a lower visual stimulation effect. However, the participants' beta brainwaves were significantly higher with latte art, which implies that latte art can attract consumers' attention (Songsamoe *et al.*, 2019). In this study, we discovered that café with latte art triggered one's beta brainwaves to a greater extent, i.e. it resulted in a more attentive state. From the perspective of taste, according to Van Diepen *et al.* (2019), the alpha brainwave also functionally inhibits sensory processing. The participants in this study stated that their taste perceptions with respect to sweetness and sourness were lower when they drank coffee without latte art than with latte art, and this result is also consistent with prior literature. Moreover, semantically congruent presentation in visual and auditory stimulation has been found to activate gamma brainwaves (Marina and Sofya, 2020) and confirm the taste-visual crossmodal effect, i.e. the congruence of two kinds of food products that the participants have seen and tasted. However, in the present study, the participants' gamma bands were not significantly increased by latte art. This discrepancy could be attributed to different stimuli used by the two studies and the different statistical methods used for data analyses. However, further study is required to explore the relationship between visual stimulation of latte art and consumers' gamma wave.

Van Doorn *et al.* (2015) reported that consumers' perception towards the intensity of the coffee with latte art (vs without art) was not significantly different. However, in this study, only the participants' taste of bitterness was not significantly affected by latte art, whereas the other two tastes (acidity and sweetness) were significantly stronger when latte art was presented. Giacalone *et al.* (2016) suggested that coffee with bitterness is considered as low-quality coffee, whereas acidity is linked to high-quality coffee (Vitzthum, 1975), which may generate more financial value (Brollo *et al.*, 2008). In this study, participants gave higher ratings for the taste of acidity and sweetness for coffee with latte art. As reported by De Pauw *et al.* (2017) that an increase in beta brainwaves is associated with sweetness, latte art may make consumers more attentive while drinking coffee, which would also be helpful for them to remember the taste. In addition, as sweetness can encourage prosocial behaviour (Schaefer

et al., 2020), presenting latte art on coffee can further enhance the social value of coffee consumption. (Spinelli *et al.*, 2017).

5.2 Limitations

This study had several limitations. The first limitation was the small sample size. As this was an experimental study, the sample size was not large enough to include participants of various backgrounds. For example, variables such as cultural background as well as one's experience of coffee drinking are worth exploring further in follow-up studies as these factors may be influential in the crossmodal effect on food and beverage selection (Piqueras-Fiszman and Spence, 2012). Moreover, consumers drink coffee for different purposes, such as for hedonic (to enjoy the coffee) or functional (to stay awake) purposes. This study focused on the hedonic aspect, which limits the generalizability of the results to include consumers for the functional purpose. The second limitation included the issues related to the experimental site. To increase the external validity of this study, a café of a five-star hotel was selected to perform the experiment where other variables such as background noise could not be avoided, although we tried to control it.

5.3 Implications

Based on the limitations, this study offers implications for future research. Spinelli *et al.* (2017) stated that coffee consumption is a multidimensional behaviour as coffee *per se* is a complex beverage in terms of sensory attributes (Giacalone *et al.*, 2016); it is almost impossible to evaluate its sensory quality by any one method. This study used objective EEG and subjective sensory evaluation of bitterness, acidity and sweetness. Future studies can shed some light on the effect of latte art on consumption behaviour through the lens of behaviour observation because sometimes research participants may not make a precise judgement on the sensory attributes of the coffee, although their sensory evaluation could be reflected by their behaviour. For example, humans and animals show rejection behaviours towards food or drinks through nausea or delayed swallowing (Turoman *et al.*, 2018). This study also examined the participants' EEG signals during the entire experiment by calculating participants' average values of the five brainwaves. However, as it was difficult to detect timely responses of participants' brainwaves towards the stimuli, an experiment based on event-related potential must be conducted to solve this problem.

To a large extent, consumers in this study perceived no difference in bitterness with or without latte art, but detected significant differences in acidity, and particularly sweetness. There are managerial implications of these findings for coffee shops. Given there was a significant increase in participants' beta brainwaves with the presence of latte art, baristas should acknowledge the benefits of having latte art on their coffee to promote their consumers' prosocial behaviour and help consumers stay attentive. If the barista is making coffee for a group of consumers sitting together, latte art would be beneficial for their socialisation. Furthermore, as latte art boosts the taste of sweetness, which would elicit responses from the reward system in the brain (van Opstal *et al.*, 2019), consumers do not need to actually add sugar to their coffee, which can help them reduce their intake of sugar and alleviate overweight and obesity.

6. Conclusion

Coffee is one of the most popular drinks worldwide, and latte art is a pattern or design that is used to decorate the surface of the coffee drink. This study explored how the presence of latte art would affect the consumers' neural activities in the brain and their perception of tastes, such as bitterness, acidity and sweetness of coffee. Results analysed from the EEG and

survey of 70 participants revealed that the alpha and beta brainwaves of the participants were significantly different when they consumed coffee with and without latte art. Their alpha brainwaves were significantly lower, whereas their beta brainwaves were significantly higher when the coffee was served with latte art. The other three brainwaves delta, theta and gamma showed no significant changes. Hence, the first research hypothesis was partially supported.

The second research hypothesis was also partially supported because the findings suggested that the participants' taste perception of sweetness was significantly stronger with latte art. Although acidity was also found to be significantly different with latte art, Cohen's *d* and Bayesian statistics showed a small effect size and anecdotal evidence for this difference. No significant difference was found in their taste of bitterness. Although limited by the small sample size and the lack of generalizability, we believe that our findings have theoretical and managerial implications that can provide valuable insight into latte art for scholars and practitioners of coffee business.

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