

1 RUNNING HEAD: TASTING ATMOSPHERICS

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3 **Tasting atmospherics:**  
4 **Taste associations with colour parameters of coffee shop interiors**  
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## ABSTRACT

Coffee is one of the world's most frequently consumed beverages, and coffee culture is an increasingly popular phenomenon across the world. Atmospheric elements are especially important for the design of coffee shops. However, it is still unclear how the visual atmospherics (e.g., colour scheme, lightness) of coffee shop interiors influence the consumer's evaluations of coffee shops and their expectations concerning the coffee beverages they serve. The present research was designed to understand the role of one aspect of the visual atmosphere, namely the colour parameters of the interiors of coffee shop, on the consumer evaluation of the coffee shops themselves and on the expected sensory properties of the coffees served there. Ratings of taste expectations, likelihood of visiting, and emotions were evaluated for each of 50 coffee shop images and averaged across 65 participants. The color parameters ( $L^*$ ,  $a^*$ ,  $b^*$ , saturation) of the coffee shop interior were calculated using digital image analysis. The results demonstrate that more reddish and lighter coloured coffee shop images were associated with the expectation that the coffee shop would serve a sweeter coffee, while more greenish and darker coloured coffee shop images were associated with more sour/bitter/tastier coffee expectations as well as a higher likelihood of visiting. Moreover, emotions, specifically feelings of calmness, mediated the relation between color parameters and taste expectations/likelihood of visiting. Taken together, these results provide evidence on the role of visual atmospherics of coffee shops on consumer evaluations and provide a number of practical implications for the coffee outlets/cafes.

*Keywords:* Visual atmospherics; Crossmodal correspondences; Coffee shop; Colour; Digital image analysis; (Multi-) Sensory Marketing

## Introduction

Coffee culture, and coffee shops, are increasingly popular across the world. Coffee is one of the world's most popular beverages, with more than 500 billion cups of coffee estimated as being consumed every year (Felton, 2018), many of them in coffee shops. In the opening decades of the 21<sup>st</sup> century, there has been a steady growth in the number of coffee shops in cities (Felton, 2018). Given the popularity and pervasiveness of coffee shops and coffee in our daily lives, it becomes increasingly important to investigate the consumers' perception of, and response to, coffee shops and coffee.

Multisensory store atmospherics constitute an important part of the consumer's total experience, and that is as true in the case of coffee shops as for any other kind of retail environment. It has been suggested that the atmosphere of the place may sometimes be more influential than the product itself (Spence et al., 2014). Multisensory atmospheric elements, including the visual, auditory, olfactory, and tactile, have all been shown to influence the coffee-drinking experience (see Spence et al., 2014; Spence & Carvalho, 2020, for reviews). For example, vision (e.g., the brightness of the lighting), audition (e.g., background noise and the sound of coffee machine), and touch (e.g., ambient temperature) have all been shown to influence the expectations and perception of consumers, and, ultimately, their coffee preferences (e.g., Spence & Carvalho, 2020, for a review).

### *The role of interior colour on consumer evaluations*

This study focuses on the role of visual atmospherics, specifically the interior colour of coffee shops, on consumer expectations of coffee shops and the coffees served therein. In a retail context, consumers often use visual cues in order to make a decision (e.g., on whether or not to enter a coffee shop) and may also help set taste expectations of the food/drinks that will be served (e.g., expectations of sweet/bitter taste of coffees, or of quality) (e.g., Carvalho & Spence, 2019; Spence & Carvalho, 2020). Visual elements of store atmospherics include everything from the interior design including the brightness of the lighting, the use of colour, not to mention the size and shape of the space (e.g., Kotler, 1974). Among them, the role of interior colour on consumer behaviour has perhaps been examined most extensively (e.g., Tantanatewin & Inkarojrit, 2018). Previous research investigated how interior colour influences consumer responses to stores (e.g., Tantanatewin & Inkarojrit, 2018). For example,

Tantanatewin and Inkarojrit manipulated the interior colours of pictures of restaurants and investigated how this impacted people's emotional responses and their likelihood of visiting the restaurant (Tantanatewin & Inkarojrit, 2018). Light and warm coloured interior (e.g., orange, light pink) were found to increase people's self-reported likelihood of visiting the venues and their pleasant emotion (the feeling of pleasure). Given such findings, the prediction would have to be that light and warm interior colours would likely also increase people's likelihood of visiting a coffee shop.

### *Crossmodal correspondences between colour and tastes*

People map features in one sensory modality onto features in other modalities in a manner that is surprisingly consistent. These associations between seemingly unrelated features in different senses are referred to as crossmodal correspondences (see Motoki & Velasco, 2021; Spence, 2011). Relevant to the present study, correspondences between colour and taste have frequently been documented in the literature (Carvalho & Spence, 2019; Spence, 2019; Wan et al., 2014). For example, pink and red are strongly associated with sweetness, yellow and green with sour, white and blue with salty, and black and brown with bitter (Spence, 2019 for a review). Research using coloured environments has been shown to influence taste in a manner consistent with such correspondences (e.g., Spence et al., 2014; Velasco et al., 2015). For example, the pink/red (and round) VR environment was associated with sweetness, while the black/dark (and angular) VR environment was mainly associated with bitterness (Chen et al., 2020). In terms of lightness/saturation-tastes correspondences, little research has been conducted to date. Mixed findings were reported for saturation-tastes correspondences (Spence, 2019, for a review). Given this evidence, it would have to be predicted that interior colours of coffee shops are associated with taste expectations (e.g., reddish colour and sweetness, darkish colour and bitterness).

### *The present research*

The present research was designed to understand the role of the interior colour of coffee shops on the evaluation of consumers. There are several novel aspects to the present research. First, no research has investigated the role of visual atmospherics on colour-taste correspondences by using a range of visual parameters (e.g.,  $L^*$ ,  $a^*$ ,  $b^*$ )

(e.g., Spence, 2019; Spence & Carvalho, 2020, for reviews). Second, the psychological mechanisms underlying colour-taste correspondences have still not been fully elaborated (e.g., Spence, 2019). Third, previous research changed the colour of almost the whole environment (e.g., Chen et al., 2020; Tantanatewin & Inkarojrit, 2018). However, in any real store setting, it would seem unlikely that the entire interior would necessarily be coloured uniformly. It is currently still somewhat unclear to what extent consumers' taste expectations/store impressions depend on the subtle, complex, and realistic visual cues of the visual atmospherics.

In order to start to fill some of these gaps in the literature, the current research implemented digital image analysis and assessed sensory and emotional evaluations of consumers (e.g., sweet expectation of coffees, calming feelings to coffee shops) to investigate the role of interior colour on people's impression of coffee shops and coffees. Digital image analysis was used to extract visual information from complicated and realistic coffee shop images. The color parameters (e.g.,  $L^*$ ,  $a^*$ ,  $b^*$ ) of the coffee shop interior were calculated. Although there are different colour spaces, the  $L^*a^*b^*$  colour space is widely used in sensory science (e.g., Wu & Sun, 2013). This is, in part, because it is perceptually uniform and the distance between different colours approximately corresponds to the human perception of colours (see Wu & Sun, 2013). Using this procedure enabled us to examine: (1) how color parameters of coffee shop interior images are associated with taste expectation of coffees and likelihood of visiting; and (2) which emotions (valence/arousal) mediate the relations between the color parameters and taste expectations/likelihood of visiting.

## Methods

### *Design and participants*

A total of 65 participants<sup>i</sup> (23 females, mean age of 40.37 yrs,  $SD = 10.07$ ) was recruited on Lancers for a monetary compensation of 150 JPY and completed the online survey on Google forms. The study was approved by the ethics committee of Miyagi University, Japan and was conducted in accordance with the Declaration of Helsinki.

Participants viewed a series of static images of coffee shops and rated their likelihood of visiting, the expectations concerning the taste of the coffee that would be served there (in terms of expected sweetness, sourness, bitterness, and tastiness), and emotions (in

terms of feeling of valence and arousal by seeing an image of a coffee shop). First, participants rated their likelihood of visiting each of 50 coffee shops shown in images.<sup>ii</sup> Next, they rated their taste expectations of coffee that would be served in each of the coffee shops (while viewing the images, once again). Next, the 50 coffee shop images were rated for valence and thereafter for arousal. Ratings of the likelihood of visiting and taste expectations were collected on a Likert scale ranging from 1 (not at all) to 7 (very much). Ratings for valence were collected from 1 (negative) to 7 (positive). Ratings for arousal were collected from 1 (calming) to 7 (arousing). The order of 50 coffee shop images was randomized for each rating. For each participant, the subjective ratings were converted to z-scores to enable a comparison of the ratings provided by different respondents. Then the mean ratings in each item across participants and for each coffee shop image was computed and used for statistical analyses. The 50 coffee shop images were selected from the internet to create as broad a range of images as possible. The other selection criteria was that the images should show no (or unnoticeable) people, coffee, foods and/or branding. Examples of coffee shop images are shown in Figure 1 and Appendix Figure A. The means (SDs) of main colour parameter are  $L^* = 46.15$  (15.48),  $a^* = 9.63$  (10.78),  $b^* = 13.53$  (15.98), saturation = 0.46 (0.19).



Figure 1. Examples of coffee shop images: (a) Special café (<https://tanosu.com/cafe/41112/>),  $L^* = 72.82$ ,  $a^* = 1.86$ ,  $b^* = 7.97$ , Saturation = 0.15; (b) Meeting house (<https://aditc.jp/2019/07/07/sendai-meetinghouse/>),  $L^* = 25.91$ ,  $a^* =$

7.10,  $b^* = 11.28$ , Saturation = 0.56; (c) Nerdy (<https://tabizine.jp/2019/05/31/264232/>),  $L^* = 33.52$ ,  $a^* = 13.50$ ,  $b^* = -17.32$ , Saturation = 0.39; (d) L'occitane café (<https://withonline.jp/lifestyle/LI7rV>).  $L^* = 64.75$ ,  $a^* = 3.81$ ,  $b^* = 41.55$ , Saturation = 0.62; (e) RK garden (<https://estate.towner.jp/cl-rk-garden/>).  $L^* = 39.80$ ,  $a^* = -7.13$ ,  $b^* = 11.87$ , Saturation = 0.31; (f) Pink holiday café (<https://www.lafary.net/sweets/46471/>).  $L^* = 52.90$ ,  $a^* = 31.88$ ,  $b^* = 21.37$ , Saturation = 0.56. All coffee shop images available online. [Links accessed 14 February 2021.]

### *Colour parameters*

The colour parameters ( $L^*$ ,  $a^*$ ,  $b^*$ , saturation) and other visual image parameters (contrast, complexity) were calculated using digital image analysis, namely the Image Processing Toolbox implemented in MATLAB. Each coffee shop image was converted to a resolution of 700×524 pixels. For each coffee shop image, the  $L^*a^*b^*$  color space parameters were computed for each pixel. The parameter  $L^*$  indicates the degree of lightness (from black to white). The parameters  $a^*$  (from green to red) and  $b^*$  (from blue to yellow) denote the two chromatic components. We also computed the saturation from the HSV (hue, saturation, value) model. The (local) contrast (i.e., the standard deviation of the pixel luminance values) and the complexity (i.e., the proportion of pixels representing object edges) of each image were also calculated. For each of the images, each of the measurements was defined as the averaged values across all of pixels.

### *Statistical analysis*

Regression analyses were performed to investigate the relations between colour measurements and subjective ratings (sweet/sour/bitter/tastiness expectation, likelihood of visiting, valence, and arousal). Each of the average subjective ratings was used as the dependent variable in each simple regression analysis. The four colour measurements ( $L^*$ ,  $a^*$ ,  $b^*$ , saturation) were used as a predictor variable in each regression model. Multiple regression analyses were also performed to investigate whether the observed effects remained significant after controlling for the other visual parameters (local contrast, complexity). For example, to test for the influence of  $L^*$  on sweetness, the other five visual measures ( $a^*$ ,  $b^*$ , saturation, local contrast, complexity) were included as control variables for the multiple regression model.

Additionally, the relations between emotions (valence/arousal) and taste expectations/likelihood of visiting were investigated using simple regression analyses.

Each of the average taste expectations (sweet/sour/bitter/tastiness) and the likelihood of visiting ratings were used as the dependent variable in simple regression analyses. The emotion ratings (valence, arousal) were used as predictor variables in each regression model. All of the analyses were performed using R software.

To determine whether emotions (valence and arousal) mediated the relations between colour measures and taste expectations/likelihood of visiting, we conducted parallel mediation analysis using the PROCESS macro for SPSS (PROCESS Model 4) with 5000 bootstrap samples. In this analysis, the colour measures for the coffee shop images (e.g.,  $L^*$ ,  $a^*$ ) were entered as the independent variable (X), each taste (e.g., expected sweetness, bitterness) as the outcome variable (Y), both valence and arousal as the mediator variables (M). If the 95% bias-corrected confidence intervals did not include zero, we regarded them as significant.

## Results

### The relations between colour measures and taste attributes, likelihood of visiting, and emotions

#### *Regression analyses*

The present analyses revealed that  $L^*$  (from black to white) and  $a^*$  (i.e., from green to red) were positively correlated with sweet expectations of coffee and arousal. In contrast,  $L^*$  and  $a^*$  were negatively correlated with sour/bitter/tastiness expectations of coffee. the analyses revealed that  $a^*$  was negatively correlated with likelihood of visiting to coffee shops and valence.  $b^*$  (i.e., from blue to yellow) was positively correlated with valence. Moreover, the present analyses also demonstrated that (local) contrast was positively correlated with expectations of sour coffee and an increased likelihood of visiting. No significant relations were found between complexity and any of the colour parameters. The results and the scatter plots are shown in Table 1 and Figure 2, respectively. After controlling for the other visual parameters, all the above findings remained significant (Table 2).

Table 1. Results of simple regression analyses: The relations between colour parameters and sensory/emotional expectations and behavioural intention.



<i>Dependent variable</i>	<i>Independent variable</i>	$\beta$	<i>SE</i>	<i>t</i>	<i>p</i>	$R^2$
Sweetness	$L^*$	0.686	0.105	6.537	<.001*	.471
	$a^*$	0.451	0.129	3.506	<.001*	.204
	$b^*$	0.258	0.139	1.853	.070	.067
	Saturation	-0.024	0.144	-0.163	.871	.001
	Complexity	0.232	0.140	1.650	.106	.054
	Contrast	-0.198	0.142	-1.397	.169	.039
Sourness	$L^*$	-0.744	0.096	-7.762	<.001*	.562
	$a^*$	-0.386	0.133	-2.889	.006*	.151
	$b^*$	-0.124	0.143	-0.866	.391	.016
	Saturation	0.139	0.143	0.969	.338	.020
	Complexity	-0.196	0.150	-1.302	.199	.035
	Contrast	0.282	0.139	2.033	.048*	.081
Bitterness	$L^*$	-0.719	0.100	-7.176	<.001	.518
	$a^*$	-0.391	0.133	-2.943	.005*	.153
	$b^*$	-0.088	0.144	-0.611	.544	.008
	Saturation	0.042	0.144	0.290	.773	.002
	Complexity	-0.206	0.141	-1.455	.152	.042
	Contrast	0.224	0.141	1.593	.118	.050
Tastiness	$L^*$	-0.435	0.130	-3.335	.002*	.189
	$a^*$	-0.402	0.132	-3.045	.004*	.162
	$b^*$	0.158	0.143	1.106	.274	.025
	Saturation	0.005	0.144	0.033	.974	.000
	Complexity	0.039	0.144	-0.273	.786	.002
	Contrast	0.239	0.140	1.704	.095	.057
Likelihood of visiting	$L^*$	-0.193	0.142	-1.364	.179	.037
	$a^*$	-0.510	0.124	-4.109	<.001*	.260
	$b^*$	0.266	0.139	1.909	.062	.071

Valence	Saturation	-0.021	0.144	-0.145	.886	.000
	Complexity	0.035	0.143	0.240	.812	.001
	Contrast	0.284	0.138	2.053	.046*	.081
	<i>L*</i>	0.094	0.144	0.656	.515	.009
	<i>a*</i>	-0.355	0.135	-2.629	.012*	.126
	<i>b*</i>	0.404	0.130	3.398	.001*	.194
	Saturation	0.010	0.144	0.066	.948	.000
	Complexity	0.238	0.140	1.697	.096	.057
	Contrast	0.242	0.140	1.725	.091	.058
Arousal	<i>L*</i>	0.530	0.122	4.332	<.001*	.281
	<i>a*</i>	0.540	0.122	4.442	<.001*	.291
	<i>b*</i>	0.037	0.144	0.254	.801	.001
	Saturation	0.143	0.143	0.997	.324	.020
	Complexity	0.247	0.140	1.764	.084	.061
	Contrast	-0.093	0.144	-0.646	.521	.009

Note: *L\**, *a\**, *b\** indicate colour parameters of coffee shop images (*L\** = black to white, *a\** = green to red, *b\** = blue to yellow).  $\beta$  = standardized regression coefficient. *SE* = standard error. *t* = t-value. *p* = p-value.  $R^2$  = R squared. Asterisk (\*) in p value indicates significance ( $p < .05$ ).

**Table 2.** Results of multiple regression analyses: The relations between emotions and sensory expectations/behavioural intention.

Dependent variable	Independent variable	$\beta$	<i>SE</i>	<i>t</i>	<i>p</i>	<i>adj.R</i>	<i>VIF</i>
Sweetness	<i>L*</i>	0.612	0.110	5.581	<.001*	0.651	3.266
	<i>a*</i>	0.458	0.107	4.291	<.001*		
	<i>b*</i>	-0.020	0.122	-0.165	.870		
	Saturation	-0.040	0.145	-0.274	.786		
	Complexity	0.216	0.096	2.257	.029*		
	Contrast	-0.107	0.095	-1.131	.265		

Sourness	<i>L*</i>	-0.716	0.098	-7.294	<.001*	0.725	4.150
	<i>a*</i>	-0.380	0.095	-4.002	<.001*		
	<i>b*</i>	0.193	0.108	1.785	.082		
	Saturation	-0.017	0.129	-0.133	.895		
	Complexity	-0.189	0.091	-2.080	.043*		
	Contrast	0.219	0.084	2.594	.013*		
Bitterness	<i>L*</i>	-0.825	0.098	-8.458	<.001*	0.724	4.127
	<i>a*</i>	-0.306	0.095	-3.220	.002*		
	<i>b*</i>	0.394	0.109	3.628	.001*		
	Saturation	-0.302	0.129	-2.344	.024*		
	Complexity	-0.225	0.085	-2.643	.012*		
	Contrast	0.203	0.084	2.408	.020*		
Tastiness	<i>L*</i>	-0.642	0.129	-4.998	<.001*	0.522	2.381
	<i>a*</i>	-0.322	0.125	-2.579	.013*		
	<i>b*</i>	0.679	0.143	4.753	<.001*		
	Saturation	-0.430	0.169	-2.538	.015*		
	Complexity	-0.165	0.112	-1.474	.148		
	Contrast	0.249	0.111	2.247	.030*		
Likelihood of visiting	<i>L*</i>	-0.324	0.125	-2.588	.013*	0.547	2.515
	<i>a*</i>	-0.532	0.122	-4.372	<.001**		
	<i>b*</i>	0.707	0.139	5.085	<.001		
	Saturation	-0.251	0.165	-0.152	.135		
	Complexity	-0.208	0.109	-1.905	.064		
	Contrast	0.292	0.108	2.706	.010*		
Valence	<i>L*</i>	-0.081	0.139	-0.583	.563	0.443	2.046
	<i>a*</i>	-0.387	0.135	-2.870	.006*		
	<i>b*</i>	0.748	0.154	4.851	<.001*		
	Saturation	-0.242	0.183	-1.325	.192		
	Complexity	-0.030	0.121	-0.244	.808		

	Contrast	0.255	0.120	2.130	.039*		
	$L^*$	0.711	0.098	7.241	<.001*	0.720	4.072
	$a^*$	0.466	0.096	4.873	<.001*		
Arousal	$b^*$	-0.559	0.109	-5.114	<.001*		
	Saturation	0.459	0.130	3.544	.001*		
	Complexity	0.297	0.086	3.456	.001*		
	Contrast	-0.084	0.085	-0.994	.326		

*Note:*  $L^*$ ,  $a^*$ ,  $b^*$  indicate colour parameters of coffee shop images ( $L^*$  = black to white,  $a^*$  = green to red,  $b^*$  = blue to yellow).  $\beta$  = standardized regression coefficient.  $SE$  = standard error.  $t$  = t-value.  $p$  = p-value.  $adj.R$  = Adjusted  $R^2$ .  $VIF$  = variance inflation factor. Asterisk (\*) in p value indicates significance ( $p < .05$ ).

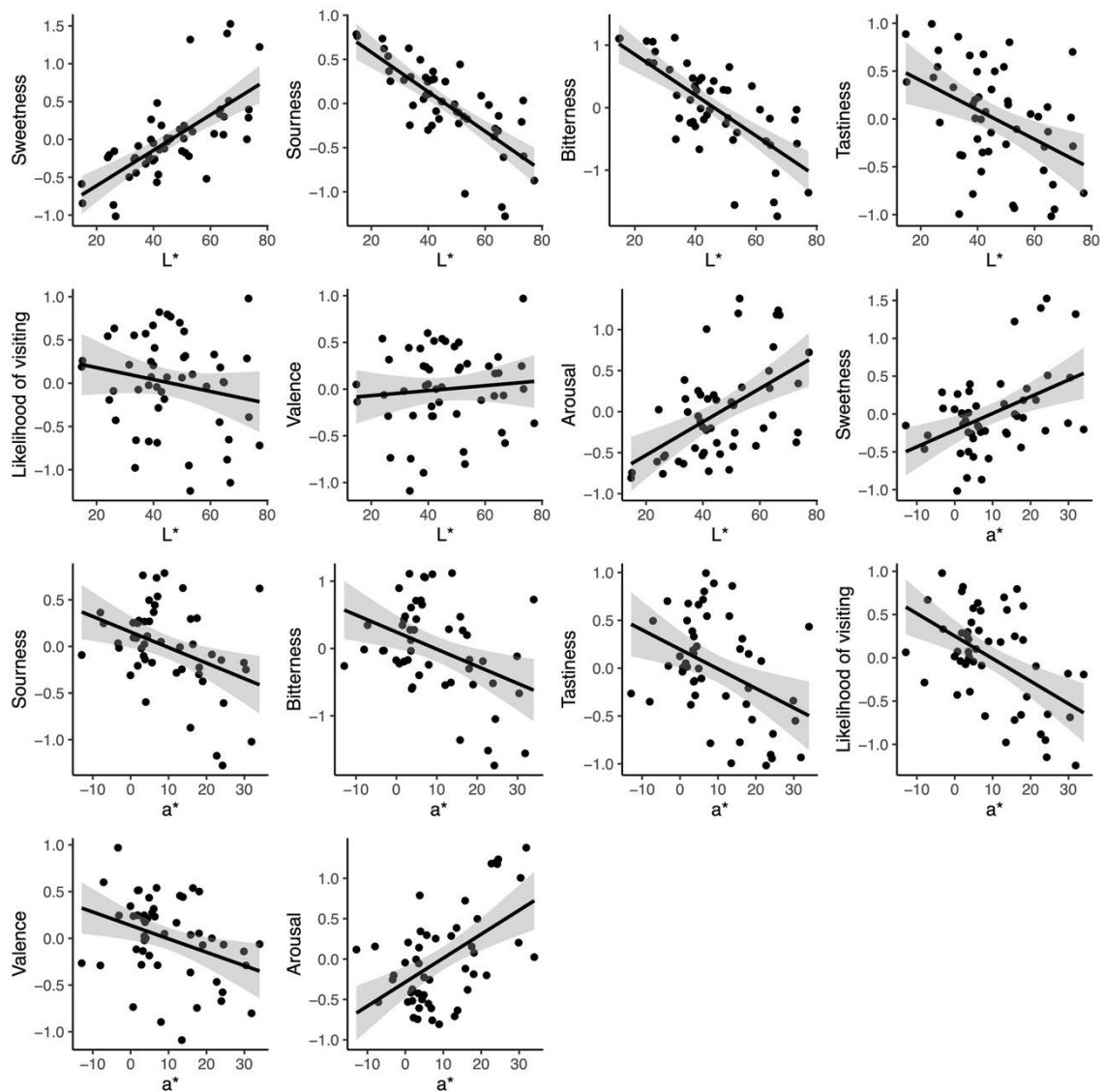


Figure 2. Scatter plot of the relations between colour parameters ( $L^*$ ,  $a^*$ ) and sensory/emotional expectations and behavioural intention. The value of  $L^*$  indicates more darkish to lighter colour. The value of  $a^*$  indicates more greenish to reddish colour. The value of sensory expectations/ behavioural intention indicates ‘not at all’ to ‘very much’ (e.g., ‘not sweet at all’ to ‘very sweet’). The valence value goes from negative to positive. The arousal value goes from calming to arousing.

### The relations between emotions and subjective measures

As might have been expected, valence was positively related with both the likelihood of visiting and the expected tastiness of the coffee. In contrast, arousal was negatively correlated with both the likelihood of visiting and with the expected tastiness of the

coffee. In other words, those coffee shop images that evoked positive and calming feelings were more likely to be rated as delivering a tastier coffee and the participants also expressed a higher likelihood of visiting (see Table 3).

Unexpectedly, valence was positively correlated with expected bitterness and sourness but there were no significant relations with sweetness. Arousal was positively correlated with expected sweetness and was negatively correlated with expected sourness and bitterness. This result indicates that those images of coffee shops that evoked positive and calming feelings were expected to be more likely to serve coffees that were more bitter and sour (see Table 3). Cafes which evoke arousing feelings were more likely to be expected to serve a sweeter-tasting coffee.

Table 3. Results of simple regression analyses: The relations between emotions and sensory expectations/behavioural intention.

<i>Dependent variable</i>	<i>Independent variable</i>	$\beta$	<i>SE</i>	<i>t</i>	<i>p</i>	$R^2$
Sweetness	Valence	-0.085	0.144	-0.594	.555	.007
	Arousal	0.727	0.099	7.325	<.001*	.528
Sourness	Valence	0.32	0.137	2.432	.019	.112
	Arousal	-0.775	0.090	-8.618	<.001*	.612
Bitterness	Valence	0.393	0.133	2.957	.005*	.154
	Arousal	-0.890	0.066	-13.550	<.001*	.793
Tastiness	Valence	0.759	0.094	8.075	<.001*	.576
	Arousal	-0.857	0.074	-11.530	<.001*	.735
Likelihood of visiting	Valence	0.893	0.065	13.720	<.001*	.797
	Arousal	-0.792	0.088	-8.983	<.001*	.627

*Note:*  $\beta$  = standardized regression coefficient. *SE* = standard error. *t* = t-value. *p* = p-value.  $R^2$  = R squared. Asterisk (\*) in p value indicates significance ( $p < .05$ ).

# **Mediating role of emotions on the relationship between colour measures and expected tastes/behavioural intention**

Given that both  $L^*$  and  $a^*$  were significantly correlated with taste expectations, the likelihood of visiting the coffee shop and the emotions evoked, we ran parallel mediation analyses using  $L^*$  and  $a^*$  as independent variables (X), emotions (both valence and arousal) as mediators (M), and taste expectation/likelihood of visiting as dependent variables (Y). The results revealed that arousal, but not valence, mediated the relationship between  $L^*$  and taste expectation/likelihood of visiting (see Figure 3, Table 4). That is, darker coffee shop images induced more calming feelings, and higher levels of calmness were associated with higher (lower) levels of expected sourness/bitterness/tastiness and the likelihood of visiting (sweetness).

The results of the mediation analyses revealed that both valence and arousal mediated the relationship between  $a^*$  and likelihood of visiting/expected tastiness (see Figure 3, Table 4). That is, more greenish coffee shops images induced more positive and calming feelings, and higher levels of positivity/calmness were associated with higher levels of expected tastiness and an increased likelihood of visiting. Additionally, the results of the mediation analyses also revealed that arousal mediated the relationship between  $a^*$  and expected tastes (see Figure 3, Table 4). That is, more greenish coffee shop images induced more calming feelings, and higher levels of calmness were associated with higher (lower) levels of expected sourness/bitterness (sweetness).

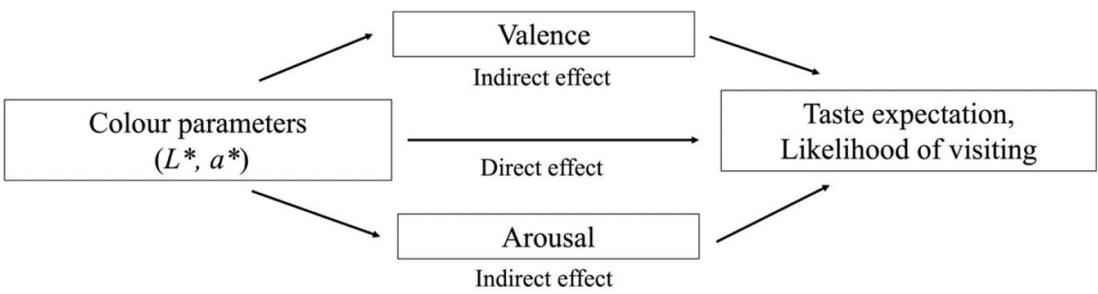


Figure 3. Schematic illustrations of mediation analyses investigating how emotions (valence and arousal) mediate the relations between colour parameters and taste expectation/likelihood of visiting.

299 Table 4. Results of mediation analyses investigating how emotions (valence and arousal) mediate the relations between colour parameters  
300 and taste expectation/likelihood of visiting.  
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Dependent variables	Independent variables	Total effect				Direct effect			Standardized indirect effect			
		b	t	p	R <sup>2</sup>	b	t	p	Valence		Arousal	
		(SE)				(SE)			b	LLCI-ULCI	b	LLCI-ULCI
Sweetness	<i>L</i> *	.023 (.004)	6.537	<.001	.471	.010 (.004)	2.467	.017	.001 (.002)	[-.043, .147]	.013 (.004)	<b> [.208, .551]</b>
	<i>a</i> *	.022 (.006)	3.506	.001	.204	.006 (.005)	1.230	.225	-.007 (.003)	<b> [-.282, -.046]</b>	.023 (.007)	<b> [.259, .686]</b>
Sourness	<i>L</i> *	-.022 (.003)	- 7.762	<.001	.562	-.017 (.003)	-5.899	<.001	.001 (.001)	[-.028, .095]	-.006 (.002)	<b> [-.318, -.081]</b>
	<i>a</i> *	-.017 (.006)	- 2.889	.006	.151	.002 (.005)	0.358	.722	.002 (.001)	[-.017, .114]	-.020 (.006)	<b> [-.690, -.241]</b>
Bitterness	<i>L</i> *	-.033 (.005)	- 7.176	<.001	.518	-.018 (.003)	-5.661	<.001	.000 (.001)	[-.022, .051]	-.015 (.004)	<b> [-.460, -.199]</b>
	<i>a</i> *	-.025 (.009)	- 2.943	.005	.153	.008 (.005)	1.528	.133	.002 (.002)	[-.006, .088]	-.035 (.010)	<b> [-.765, -.296]</b>
Tastiness	<i>L</i> *	-.015 (.005)	- 3.348	.002	.189	-.009 (.002)	-4.174	<.001	.002 (.003)	[-.089, .221]	-.008 (.002)	<b> [-.344, -.115]</b>



	$a^*$	-.020 (.007)	- 3.045	.004	.162	.007 (.003)	2.064	.045	-.008 (.003)	<b>[-.273, -.050]</b>	-.019 (.005)	<b>[-.552, -.196]</b>
Likelihood of visiting	$L^*$	-.007 (.005)	- 1.364	.179	.037	-.001 (.002)	-0.747	.459	.002 (.003)	[-.106, .261]	-.008 (.002)	<b>[-.338, -.117]</b>
	$a^*$	-.026 (.006)	- 4.110	<.001	.260	-.003 (.002)	-1.232	.224	-.012 (.005)	<b>[-.371, -.074]</b>	-.012 (.004)	<b>[-.347, -.113]</b>

302 *Note:*  $L^*$ ,  $a^*$  indicate colour parameters of coffee shop images ( $L^*$  = black to white,  $a^*$  = green to red).  $\beta$  = standardized regression coefficient.  $SE$  = standard  
 303 error.  $t$  = t-value.  $p$  = p-value.  $R^2$  = R-squared. BLLCI-ULCI = lower and upper limit confidence interval 95% with bootstrapping. Valence included as a covariate.  
 304 Bold indicates significant indirect effects ( $p < .05$ ). Unstandardized regression coefficients reported unless otherwise noted.

**Serial mediation analysis:  $L^*/a^* \rightarrow$ arousal  $\rightarrow$  taste expectation  $\rightarrow$  likelihood of visiting**

The results of mediation analyses demonstrated that the feeling of calmness mediated the effects of both  $L^*$  and  $a^*$  on taste expectations and the likelihood of visiting. For exploratory purposes, a pair of serial mediation analyses were conducted to confirm a hypothetical causal linking ( $L^*/a^* \rightarrow$ arousal  $\rightarrow$  expected tastiness  $\rightarrow$  likelihood of visiting) (PROCESS Model 6) with 5000 bootstrap samples. In the analyses, the colour measures for the coffee shop images (i.e.,  $L^*$ ,  $a^*$ ) were entered as the independent variable (X), arousal and taste expectation as the serial mediator variables ( $M_1$  and  $M_2$ ), and likelihood of visiting as the dependent variable (Y). Valence was included as a covariate. If the 95% bias-corrected confidence intervals did not include zero, they were regarded as significant.

The results show that the two mediators (arousal and taste expectations) in a serial order fully mediate the relationship between  $L^*$  and likelihood of visiting (Figure 4, Table 5). That is, more darkish colour (lower  $L^*$ ) increased the feeling of calmness, which could, in turn, increase taste expectations and thus increase the expected likelihood of visiting. In contrast, the two mediators (arousal and taste expectations) did not serially mediate the relations between  $a^*$  and the likelihood of visiting. It should be noted that we also assessed the role of valence in a serial mediation analysis (i.e.,  $a^* \rightarrow$ valence  $\rightarrow$  expected tastiness  $\rightarrow$  likelihood of visiting). However, no significant indirect effect was observed.

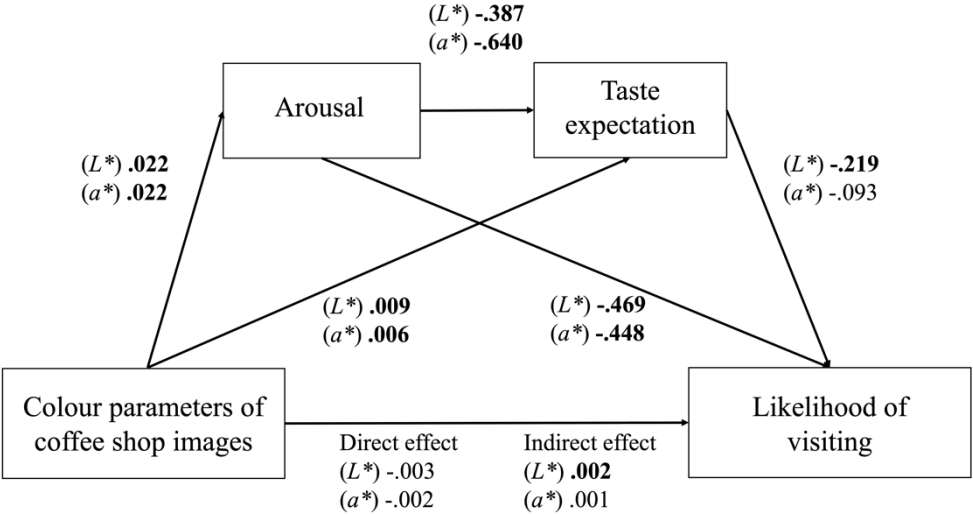


Figure 4. Results of serial mediation analyses investigating how arousal and taste expectations serially mediate the relations between colour parameters and likelihood of visiting.  $L^*$ ,  $a^*$  indicate colour parameters of coffee shop images ( $L^*$  = black to white,  $a^*$  = green to red). Unstandardized regression coefficients are reported. Valence included as a covariate. Bold indicates significant effects ( $p < .05$ ).

Table 5. Results of serial mediation analyses: Colour parameters ( $L^*$ ,  $a^*$ ) → arousal → expected tastiness → likelihood of visiting.

Independent variables	Total effect				Direct effect			Standardized indirect effect					
	b (SE)	t	p	$R^2$	b (SE)	t	p	$L^*/a^* \rightarrow$ Arousal $\rightarrow$ Likelihood of visiting		$L^*/a^* \rightarrow$ Tastiness $\rightarrow$ Likelihood of visiting		$L^*/a^* \rightarrow$ Arousal $\rightarrow$ Tastiness $\rightarrow$ Likelihood of visiting	
								b (SE)	LLCI-ULCI	b (SE)	LLCI-ULCI	b (SE)	LLCI-ULCI
$L^*$	-.001 (.002)	- 5.386	<.001	.874	-.003 (.002)	- 1.670	.102	-.296 (.063)	<b>[-.436, -.186]</b>	.058 (.039)	<b> [.005, .158]</b>	.053 (.031)	<b> [.006, .130]</b>
$a^*$	-.011 (.003)	- 3.542	<.001	.840	-.002 (.002)	- 0.914	.366	-.194 (.068)	<b>[-.346, -.083]</b>	-.011 (.016)	[-.052, .013]	.026 (.031)	[-.026, .096]

Note:  $L^*$ ,  $a^*$  indicate colour parameters of coffee shop images ( $L^*$  = black to white,  $a^*$  = green to red).  $\beta$  = standardized regression coefficient.  $SE$  = standard error.  $t$  = t-value.  $p$  = p-value.  $R^2$  = R-squared. LLCI-ULCI = lower and upper limit confidence interval 95% with bootstrapping. Valence included as a covariate. Bold indicates significant indirect effects ( $p < .05$ ). Unstandardized regression coefficients reported unless otherwise noted.

## General discussion

The present study investigated the role of the visual parameters of the images of coffee shops on the evaluations of consumers. Using image analysis, the findings revealed that consumers associate specific visual parameters of coffee shops with particular taste expectations and behavioural intentions. Specifically, more reddish and lighter-coloured coffee shop interiors were associated with the expectation of a sweeter tasting coffee being served, while a more greenish and darker colour was associated with expectations of a more sour, bitter, and tastier coffee, as well as calming feelings. An increased likelihood of visiting and positivity were also expected from greenish coffee shops. Moreover, emotions, specifically calming feelings, were shown to mediate the relationships between the color parameters and taste expectations/likelihood of visiting. Taken together, therefore, these findings provide evidence concerning the way in which consumers associate specific visual parameters with coffee shop and coffee evaluations and practical implications for coffee shop industries.

### *Using image analysis of store environments to study colour-taste correspondences*

This study adds new evidence concerning crossmodal correspondence between colour and taste. People associate colours with tastes in a manner that is non-random (e.g., Carvalho & Spence, 2019; Spence, 2019; Wan et al., 2014). For example, pink and red are strongly associated with sweetness, yellow and green with sour, white and blue with salty, and black and brown with bitter (Spence, 2019, for a review). However, as yet, no research has investigated colour-taste correspondences on visual atmospherics using colour image analysis. Moreover, previous research has coloured most parts of the visual scene leaving unanswered the question of how subtle and complicated colour differences of real-life environments influence taste matching/expectations (see Spence, 2020b). Using digital image analysis, the current findings investigated how consumers tend to associate a range of colour parameters ( $a^*$ ,  $L^*$ ,  $b^*$ , saturation) with specific taste expectations. Our findings reveal that  $a^*$  and  $L^*$  (but not  $b^*$  and saturation) are significantly associated with sweet, sour, and bitter taste expectations. In line with previous findings on colour (hue)-taste correspondences (Spence, 2019), more reddish colour (higher  $a^*$  value) is associated with the expectation of a sweeter coffee, while a more greenish colour (lower  $a^*$  value) is associated with more sour/bitter expectations

of coffee. Our results also suggest that previous findings concerning the colour of coffee cups (e.g., Carvalho & Spence, 2019) can be extended to environmental colour. The findings reported here provide additional evidence on colour-taste correspondences by using image analysis of real-life coffee shop environments.

This study also investigated how colour lightness and saturation are associated with tastes. Colour lightness and saturation are two of three main dimensions of colour. However, the majority of the previous research has focused on the associations that people have with specific hues (e.g., red, green, yellow) (Spence, 2019, for a review). Relatively little attention has been paid to colour lightness and saturation and their relations with taste (but see Bscheiden et al., 2020; Gal et al., 2007). A much smaller literature has addressed questions related to the role of saturation and colour lightness on tastes (Spence, 2019). Specifically, our findings suggest that lighter colour (higher  $L^*$  value) is associated with sweeter expectations of the coffee that coffee shops serve, while a darker coloured interior (lower  $L^*$  value) is associated with sour and bitter taste expectations instead. Consistent with the fact that the effects of colour saturation of food and drink products on taste expectations and evaluations are mixed (Spence, 2019), no significant relations were observed between saturation and any of the taste ratings. These findings further our understanding of colour-taste correspondences and demonstrate how consumers associate colour lightness and saturation with taste expectations.

#### *Support for colour-in-context theory*

Our findings might be explained by colour-in-context theory (e.g., Elliot & Maier, 2012). The theory proposes that colour associations with meaning are determined by the contexts in which they occur. The effects of interior store colour on consumer preferences might differ in contexts (e.g., store types such as restaurants, coffee shops). Previous research revealed that the interior of lighter and warmer colour (e.g., orange, light pink) increases the likelihood of visiting a restaurant (Tantanatewin & Inkarojrit, 2018). On the other hand, the darker lighting of restaurants increases the choice of unhealthy (vs. healthy) food choices (Biswas et al., 2017). Our findings suggest that darker and cooler coloured interior (i.e., darkish and greenish) increase the self-reported likelihood of visiting coffee shops and the expected tastiness of the coffee. Moreover, participants felt more positive valence and calming emotions on the basis of

such coffee shop images, and these emotions, in turn, led to higher anticipated tastiness and likelihood of visiting. Together, these findings provide moderate support for colour-in-context theory and the effects of interior colour might depend on the store and/or food types.

#### *Cognitive mechanisms underpinning colour-taste correspondences*

Our findings concerning colour-taste correspondences might be explained by the emotional mediation account (e.g., Motoki & Velasco, 2021; Wang & Spence, 2017), which has recently been suggested as one of the potential underlying mechanism of crossmodal correspondences involving tastes (e.g., Motoki & Velasco, 2021). Our findings demonstrated that  $L^*$  and  $a^*$  influence taste expectations via arousal. Specifically, a more greenish and darker colour increases calming emotions, which lead to more sour and bitter taste expectations for coffee. Meanwhile, a more reddish and lighter colour increases arousing emotions, which lead to sweeter expectation of coffee. However, it should be noted that the relations between arousal and taste expectations are inconsistent with previous findings on shape-taste correspondences (e.g., Motoki & Velasco, 2021).

Motoki and Velasco (2021) suggest that lower arousal (higher arousal) leads to sweet (sour, bitter) expectations. The direction of emotions (i.e., arousing or calming) might be different for colour-taste versus shape-taste correspondences. Given colour-in-context theory (e.g., Elliot & Maier, 2012), our context, that is coffee shop and coffee, might also be expected to influence any associations of colour with the emotional meanings that are evoked. Although the present research focuses on the emotional mediation account, it should be noted that alternative explanations (e.g., associative learning) might also be relevant for our findings (e.g., Spence, 2019).

#### *Limitations and directions for future research*

Our study has several limitations. First, our participants were all Japanese. Relevant here, it has been suggested that different cultures may sometimes attach different meanings (and/or emotions) to colours (Wan et al., 2014). Some modest cross-cultural differences in colour-taste associations have also been reported (Wan et al., 2014). Future research needs to investigate whether our findings can easily be generalized to participants from other cultural backgrounds. Second, the particular set of stimuli

chosen for this study might also have influenced the results that were obtained. It seems possible that the stimuli used in our study may have been subject to confounding influences. For example, the coffee shop stimuli seem differ in terms of colour parameters as well as the size and the number of pieces of furniture and cutlery, angles of photos, and so on. Even though we selected a number of stimuli to cancel out the potential confounding factors, it seems undeniable that our findings might be influenced by the confounding factors. We selected the coffee shop images to create a broad range of images. However, a random selection of coffee shop images might also generate different (or perhaps less significant) findings. Future research should therefore aim to clarify just how important stimulus selection is to the pattern of results obtained. Moreover, we used static images and this procedure might be expected to reduce the ecological validity (e.g., when compared to dynamic video footage). Incorporating immersive technologies into the experiment might help to improve the ecological validity (Bangcuyo et al., 2015) and this procedure can allow us to test for whether colour parameters of coffee shops actually change the perceived taste of coffee. This procedure could be also useful for checking whether there are differences in taste experiences between the created immersive coffee shop and an actual coffee shop (see Lichters, Möslin, Sarstedt, & Scharf, 2021). Another limitation of the present study is that the way in which we calculated colour parameters might be expected to influence the results. We computed the averaged values of all of pixels in a coffee shop image. This way of calculation cannot consider the variability or non-linear relationship of colour parameters. Future study might therefore want to consider the issues by using the proportion of pixels with above-average values and/or the variance of the values in each color space dimension. One additional limitation that is worth mentioning is that we did not collect information concerning whether participants are colour-blind (though, of course, our sample is likely to be representative of real-world distributions in this regard). Finally, an open question is whether visual parameters of coffee shop interiors predict the taste expectation and likelihood of visiting. Future research will need to investigate the issue by using machine learning approaches.

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(a)



(b)



(c)



(d)



(e)



(f)

524

525 Appendix Figure A. Examples of coffee shop images: (a) Blue bottle coffee  
 526 (<https://bianse.jp/bluebottlecoffee/>); (b) Café carat  
 527 (<https://tabelog.com/tokyo/A1317/A131701/13003429/>); (c) Mighty purple café  
 528 (<https://love-super-travel.net/guam-etc/guam/42073/>); (d) Rock café  
 529 (<https://tabihiro.jp/gourmet/s/309744-kani-ruckcafe/menu/189722/>); (e) Ver ' s garden  
 530 ([https://www.konest.com/contents/gourmet\\_mise\\_detail.html?id=20221](https://www.konest.com/contents/gourmet_mise_detail.html?id=20221)); (f) Pink pool  
 531 café (<https://ameblo.jp/wasabi-2526/entry-12388956700.html>). All coffee shop images  
 532 available online. [Links accessed 21 April 2021.]

533

<sup>i</sup> The sample size ( $n = 65$ ) exceeded the required sample sizes to estimate a 95% confidence interval for a population mean by assuming that a margin of error ( $E$ ) of 1.5% and the population standard deviation ( $\sigma$ ) of 5.

<sup>ii</sup> Given the previous research on colour-taste correspondences in coffee cups (Carvalho & Spence, 2019), a medium-to-large effect size could be assumed at least. *A priori* power analysis by G\*power indicated that the number of stimuli (i.e., 50 coffee shop images) was sufficient to detect a medium-to-large effect size ( $f^2 = 0.2$ ) with 80% power at an alpha level 0.05.