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The effect of eye movements and cultural factors on product color selection

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Abstract

A color is a powerful tool used to attract people's attention and to entice them to purchase a product. However, the way in which a specific color influences people's color selection and the role of their eye movements and cultural factors in this process remain unknown. In this study, to delve into this problem, we designed an experiment to determine the influence of specific colors on people's product preferences by using an eye-tracking device, intending to identify the role of their eye movements and cultural factors. Based on the experimental data, a detailed influence path model was built to describe the effect of specific colors on product evaluations by an integrated moderation and mediation analysis. Our findings show that in the influence process, the effects of specific colors on product evaluations are mediated by eye movements. Additionally, cultural factors partly moderate the process as an influencing factor. The research findings from this study have important implications for user-centered product design and visual marketing management.

Keywords: Eye-tracking, Visual analytics, Color preferences, Cultural variation, User-centered design

Introduction

To improve usability and user satisfaction, user-centered design [1], participatory design [2], and human-centric integrated approaches [3–5] that take into account both human and system behaviors have been widely applied in the design and development of many innovative application systems and products.

Under the concept of user-centered design, it is important to consider usability factors from the viewpoint of users. Among many factors, color is a powerful tool used to attract a person's attention and to entice people to purchase a product [6], as color influences the consumer's evaluation of a product [7]. Many merchants have aimed to attract customers' attention to their products by using different colors or combinations of them. However, according to prior research on color preferences, people's culture and geographical factors play an important role in their color preferences [8], suggesting that for customers from different cultures, the color strategy used for products may need to be adjusted to obtain more sales. For instance, red color elements have been used in many products and advertisement designs for Chinese customers because according to some studies, one's cultural factors directly affect one's color preference, and red is a preferred color for people with a Chinese cultural background [9]. However, there is not enough objective evidence to prove that these stereotypes (a set idea that people have about what someone or something is like) are helpful in product color design.

Eye-tracking devices have been applied in a variety of different research fields, including color preference analysis. For instance, Chua et al. found that Americans are different from Chinese in terms of viewing patterns [10]. However, regarding the issue of how specific colors influence people's color decisions in selecting a final product, the role of people's eye movements and cultural factors remains unknown, especially for Asians, who have distinct but similar cultures.

Generally, cultural factors involve various aspects, such as traditions, religions, languages, ethics, and values. In this study, we considered the nation to represent a combination of cultural factors and recruited two groups of subjects from two different countries. Therefore, this paper focuses on Asians' cultural differences and aims to identify the role of cultural factors and eye movements in product selection by using eye-tracking devices. To accomplish our goal, an eye-tracking device-based experiment was first designed and implemented. Then, based on those results, a difference analysis was used to identify whether a difference in eye movements existed between Japanese and Chinese subjects.

On this basis, to confirm the relationships among colors, a person's cultural factors, eye movements and the person's final product selection, detailed moderation and mediation tests were used to confirm specific colors' influence path on product selection. Specifically, moderation tests can be used to identify moderator variables on which the relationship between two variables depends; mediation analysis is a group of methods employed to understand a known relationship by exploring the underlying mechanism or process by which one variable influences another variable through a mediator variable. The research findings and conclusion from this paper have important implications for user-centered product design and visual marketing management.

This paper is an extended version of our previous conference articles [11, 12]. The remainder of this paper is organized as follows: An overview of related studies on eye-movement analysis, color preference analysis and the integration of moderation and mediation tests are provided in "Related studies and hypotheses Section" with related empirical hypotheses. In "Methodology Section", the experimental design, definitions of variables and description of the dataset are provided. Then, the analysis results and discussion are provided in "Analysis and discussion Section". Finally, we summarize the research results and provide our perspective regarding promising future research in "Conclusion Section".

Related studies and hypotheses

Analysis of eye-tracking experiments

Eye-tracking technologies have been used in various research fields, such as sports and health care. With a variety of eye movement measurements, many experiments and analyses have been performed by researchers. For example, Litchfield et al. carried out eye-tracking experiments on pulmonary nodule detection photos, and a variety of eye-movement metrics were used to investigate differences between radiographers (experienced and inexperienced) [13]. In the research of Vaeyens et al. [14] on soccer plays, the authors examined soccer players (successful and less successful) to predict their decision-making processes and skill levels by using eye-movement measures related to search rates. Moreover, in addition to investigating the influence on eye-movement measures in response to visual stimulation, subject characteristics such as age, sex and culture have also been considered factors in many eye-movement experiments [7].

According to a universal model of eye-tracking experiments proposed by Wedel et al. [15], the influencing factors within an eye-tracking experiment are classified into two types: top-down and bottom-up factors. In detail, top-down factors are characteristics of people, such as age and culture, that do not easily change with the experimental environment. Bottom-up factors are the measures from the visual stimulation that are incorporated in the experimental environment (e.g., the visual stimulation from the products' color design). Both types of factors affect subjects' eye-movement measures, which can be recorded by an eye-tracking device, and lead to outcomes, such as an action or an evaluation from the subjects.

Analysis of culture-based color preference

Color is a powerful tool that is used in a variety of fields of research, such as image detection & identification [16, 17] and digital printing [18]. Among the aspects of color, the effects on human performance and cognitive interpretation provide important evidence suggesting potential consumer reactions that further influences their evaluation of products [19]. However, regarding the issue of how specific colors influence product color selection, the role of people's eye movements and cultural factors in this process remains unknown.

Many researchers have been interested in culture-based color preference analyses. For example, based on Saito's research on Asian people's color preference, which was conducted using questionnaires, unique color preferences were shown by individuals from different areas (counties) in Asia [20], which suggested that one's culture and geographical factors may play important roles in one's color preferences. Moreover, some prior research has suggested that people's cultural factors directly influence their color preferences. According to Zeng et al.'s work, red color elements are preferred by Chinese people, and the use of red color elements may attract more attention from Chinese consumers and promote sales [9]. However, there is not enough objective evidence to prove that these stereotypes (a set idea that people have about what someone or something is like) are helpful in product color design.

Detailed information on one's eye movements is relatively easy to collect using eye-tracking devices. Many researchers have examined the influence of cultural factors on eye movements. For example, Lee et al. found that people's eye movements indicated their color preference by exploring the possible relationships between the characteristics of scan-paths and color preferences [21]. The authors did not discuss the effect of cultural factors on color preferences in this article.

Summary and hypotheses

In summary, people's evaluations can be influenced by a product's color, and in this process, cultural factors and their eye movements may play an important role. However, prior studies using eye trackers have typically analyzed Asians as a group but did not discuss the effect of similar but distinct cultures on color preferences, such as the difference between Japanese and Chinese individuals.

Therefore, the following hypotheses were developed to identify these differences and the usefulness of eye-movement measures in the moderation and mediation test steps (undifferentiated measures are not useful for moderation and mediation tests).

H1: When individuals are selecting products with different colors, differences exist in eye-movement measures between individuals due to different cultural factors.

Moreover, to identify the influence of specific colors on product selection, on the basis of prior research results and the actual experimental environment, two hypotheses are proposed.

H2: When subjects are selecting products with different colors, their eye-movement measures mediate the process by which specific colors influence product evaluation.

H3: When subjects are selecting products with different colors, cultural factors moderate the process by which specific colors influence product evaluations.

Methodology

Experimental model and design

To test our proposed hypotheses, we designed a set of experiments based on a universal model [15]. As shown in Fig. 1, product colors and cultural factors represent the corresponding bottom-up and top-down factors, respectively, in our model. Then, through the subjects' decision-making process, which can be described by their eye-movement measures, product evaluation scores are used as the downstream effects (the benefits or costs that will ultimately result from decisions made) to represent their final product selection.

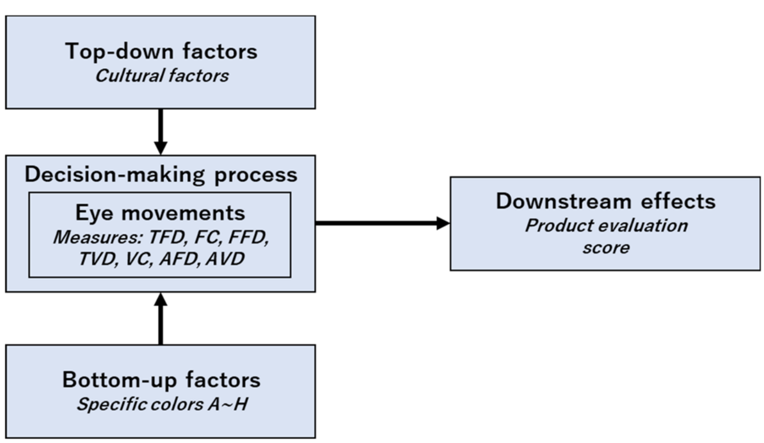

Fig. 1 The eye-tracking experimental model

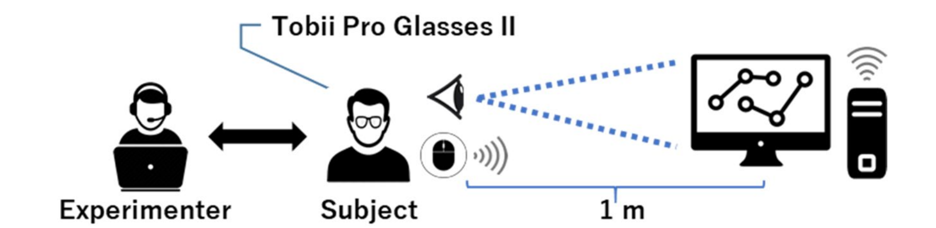

Fig. 2 The experimental environment

Table 1 Details of the subjects in the experiments

Number of subjects	40
Male:Female	1:1
Age (mean & standard deviation)	20.97 & 4.36
Health condition	Good
Number of experiments	280 (40 × 7)*

*A total of 40 people, each doing seven experiments

Therefore, based on our proposed experimental model, we set up the experimental task for all subjects by asking them to rank the products (which were of the same categories but different colors) that they looked at according to their preferences.

The design of our experiment is shown in Fig. 2. A set of Tobii Pro Glasses II eye-tracking devices was used to collect subjects' eye-movement data. Meanwhile, one meter in front of the subjects, a PC monitor (Apple iMac, 27-inch monitor, 2560 × 1440, all other parameters default) was used to show our experimental slides (photos of products) as the main visual stimulation. Subjects could advance the slides themselves without moving their line of sight with a wireless mouse. The experimenter remained out of the subjects' sight and recorded their choices by listening to the subjects' verbal reports. During the experiment, a 40-W fluorescent tube was used to provide the standard levels of lighting.

Finally, to simulate the process of product color selection scenarios, a total of 40 college students, including 30 Chinese overseas students, were invited to participate in our experiment. To reduce the influence of the current environment on their cultural history, the invited overseas students were first-year college students who were new to Japan. The details of the subjects involved are shown in Table 1. The subjects' eye-movement data and their final product evaluation results were collected by the eye-tracking device and the questionnaire after the experiments, respectively.

For our experimental slides, a set of simple color blocks and six categories of products (snacks, cosmetics, clothes, pharmaceuticals, and large and small electronic products) were used as the visual stimuli to reduce the extraneous effect of the subjects' preference for specific products. According to one study, these categories of products are among the most popular with Chinese tourists [22]. Based on this, the product pictures to be used in the experiment were selected, which included daily products such as normal electric cookers (using image processing software to change

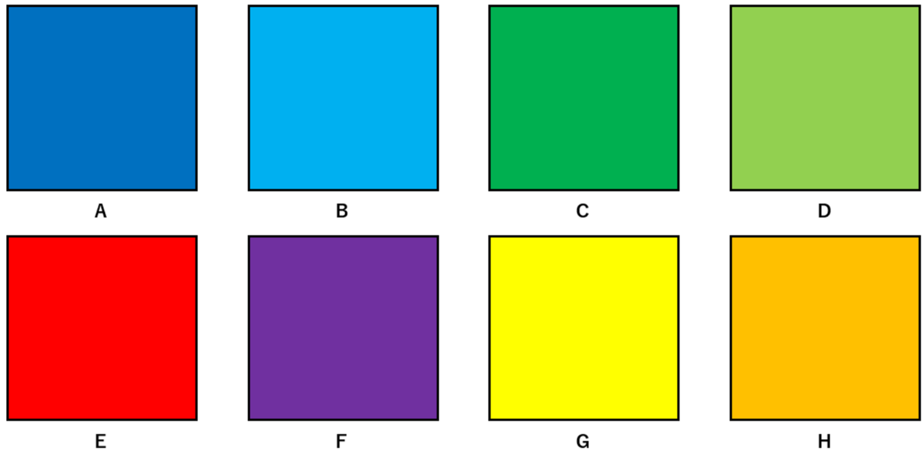

Fig. 3 Eight NCS colors for the visual stimuli

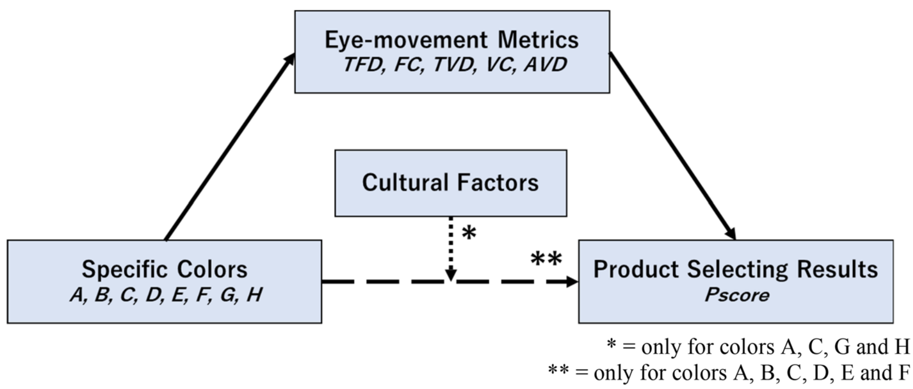

Fig. 4 The influence path model

their main color design), and these product pictures did not have any information such as the brand or design features to influence subjects' selection.

As shown in Fig. 3, each product was shown eight times in eight different NCS colors, color A (blue), B (light blue), C (green), D (light green), E (red), F (violet), G (yellow) and H (orange), presented in random order. Notably, Fig. 3 shows the calibration picture to promote subjects' adaptation to the experiment; the product pictures did not only have a single color (instead, the corresponding color was the dominant tone in the product design). Each block contained 1 image of a product in one color (or just a simple color). For the subsequent eye movement analysis, each block was assigned a different AOI (Areas of Interest) (Fig. 4).

Dataset

During our data collection period, from November 1 to December 30, 2018, a total of 2254 raw samples of eye movements were recorded by our system. In addition, the subjects' demographic data and the product evaluation data were collected by questionnaires in the same session.

Variables

Four main types of variables were considered in our analysis, including colors, cultural factors, measures of eye movements and evaluations from subjects.

Colors

As mentioned above, eight different NCS colors (blue, light blue, green, light green, red, violet, yellow and orange) were assigned letters from A to H, which corresponded to the following virtual variables: C_A, C_B, C_C, C_D, C_E, C_F, C_G, and C_H.

$$C_i = \begin{cases} 0 & C \\ 1 & J \end{cases}, where\ i \in \{A, B, C, D, E, F, G, H\} \quad (1)$$

Cultural factors

To represent cultural factors, in this paper, we defined the cultural factors as a logical variable, *Cul*, because people from only two countries were considered in our study, Japan and China.

$$Cul = \begin{cases} 0 & \text{Chinese} \\ 1 & \text{Japanese} \end{cases} \quad (2)$$

Eye-movement measures

Based on prior studies, seven measures were used to describe the subjects' eye movements. Each of the measures was collected by a Tobii II eye tracker, including the total fixation duration (TFD), fixation count (FC), first fixation duration (FFD), total visit duration (TVD), visit count (VC), average fixation duration (AFD) and average visit duration (AVD). These measures were recorded and obtained for each AOI. The details of these measures are shown in Table 2.

Product evaluation

For each experimental slide, a subjective ranking by the subjects of the products in the 8 colors was calculated as a score (*Pscore*). For example, if a subject chose blue (AOI "A") as the best color (product), then this color's *Pscore* for this subject was 1.

Table 2 Details of eye-tracking measures

Measures	Detail
TFD	Total fixation duration: the summed duration of all fixations to an AOI
AFD	Average fixation duration: the average value of all fixation durations
FFD	First fixation duration: the duration of the first fixation on an object
FC	Fixation count: the number of fixation points within the AOI
TVD	Total visit duration: the summed duration of all visits to an AOI
AVD	Average visit duration: the average value of all visit durations
VC	Visit count: the number of visits to all AOIs

Analysis and discussion

To test our proposed hypotheses, a Mann–Whitney U test and a set of regression analysis-based moderation and mediation tests were performed by using the analysis tool SPSS Statistics 25.

First, the Mann–Whitney U test was applied to investigate hypothesis H1. As shown in Table 3, a significant difference (p-value < 0.01) in the eye-movement measures existed between the Chinese and Japanese subjects, with the exception of the measure FFD (first fixation duration; p-value = 0.553 > 0.05). The results showed that there were higher levels of eye movements for the Chinese subjects (z-value < 0). For example, Chinese people engaged in more comparative actions when selecting products with different colors. This result also suggested that cultural factors were related to eye movements when selecting products. H1 was supported.

Next, to determine the roles of cultural factors and eye movements on the influence of specific colors, moderation [23] and mediation [24] tests were applied in this study. To combine moderation and mediation analyses, we used the piecemeal approach [25], which incorporates moderation and mediation in a piecemeal manner and interprets their results jointly.

On the other hand, with the exception of AFD and FFD (r < 0.2, p > 0.05), there were weak positive correlations between other eye-movement measures and Pscores. Therefore, to complete the analysis, we needed to perform a regression analysis many times. In this analysis, we defined the colors (C_A, C_B, C_C, C_D, C_E, C_F, C_G, and C_H) as X (independent

Table 3 Comparison of eye movements between different cultures

Group	*N*	Mean rank	*U*	*Z*	*P*	Effect size
TFD						
CHN	1770	1191.33	315,361.500	− 8.904	0.000	− 0.188
JPN	484	894.07				
FC						
CHN	1770	1173.20	347,454.500	− 6.389	0.000	− 0.135
JPN	484	960.38				
FFD						
CHN	1770	1131.75	420,809.000	− 0.594	0.553	− 0.013
JPN	484	1111.94				
TVD						
CHN	1770	1188.44	320,477.000	− 8.501	0.000	− 0.179
JPN	484	904.64				
VC						
CHN	1770	1177.87	339,189.500	− 7.055	0.000	0.149
JPN	484	943.30				
AFD						
CHN	1770	1173.10	343,313.500	− 6.638	0.000	− 0.140
JPN	484	951.83				
AVD						
CHN	1770	1161.34	366,265.000	− 4.859	0.000	− 0.102
JPN	484	999.25				

Mean Rank = the value relies on scores being ranked from lowest to highest;

U = *U*-value for the Mann–Whitney test for the comparison of calculations with those of another program or test variable), cultural factors *Cul* as Z (moderator variable), eye-movement measure (TFD, FC, TVD, VC, AVD) as M (mediating variable) and product evaluation score *Pscore* as Y (dependent variable).

Mediation test

First, the mediator effect of variable M between the variables of Y and X was tested. In this test, three regression equations were checked.

Step 1. First, we regressed Y on X to test the direct relationship between colors and Pscores.

$$Y_{C_i} = a_{0i} + b_{0Xi}X + e_{0Yi}, where\ i \in \{A, B, C, D, E, F, G, H\} \tag{3}$$

As shown in Table 4, all the specific colors directly influenced subjects' Pscores (i.e., b_{0X} is significant), which means that X is related to Y (e_{0Yi} is the error term). Therefore, the next step in the mediation test could be performed without any adjustments.

Step 2. Second, we regressed M on X to test the influence of eye-movement measures on Pscores.

$$M_{ij} = a_{1ij} + b_{1Xij}X + e_{1Mij}, where\ i \in \{A, B, C, D, E, F, G, H\},$$

$$j \in \{TFD, FC, TVD, VC, AVD\} \tag{4}$$

As shown in Table 5, almost all of the colors influenced the subjects' eye-movement measures (i.e., b_{1X} is significant), except for color E on TFD and colors A, B, C, G and H on AVD, which means that X is related to M (e_{1Mij} is the error term). With the removal of these combinations, the next step of the mediation test could be performed.

Step 3. Last, to assess the mediated effect between colors and Pscores, we regressed Y on X and M.

$$Y_{C_i} = a_{2ij} + b_{2Xij}X + b_{2Mij}M + e_{2Yij}, where\ i \in \{A, B, C, D, E, F, G, H\},$$

$$j \in \{TFD, FC, TVD, VC, AVD\} \tag{5}$$

As shown in Table 6, the results indicated that a mediation effect existed in all tested data (i.e., b_{2M} is significant and b_{2X} is nonsignificant or significant but smaller than b_{0X}), except for color E on TFD and colors A, B, C, G and H on AVD, which means that M is

Table 4 Results of the mediation test step 1

X	b_{0X}
C_A	− 1.418***
C_B	− 0.824***
C_C	0.952***
C_D	0.307**
C_E	− 0.498***
C_F	1.517***
C_G	0.378***
C_H	− 0.414***

**p value < 0.05, ***p value < 0.01

Table 5 Results of the mediation test step 2

X	b_{1X}				
	M : *TFD*	*M* : *FC*	*M* : *TVD*	*M* : *XVC*	*M* : *AVD*
C_A	− 0.231***	− 0.244***	− 0.238***	− 0.226***	− 0.011$^{n.s}$
C_B	0.075***	0.081***	0.081***	0.090***	− 0.008$^{n.s}$
C_C	0.107***	0.126***	0.110***	0.127***	− 0.018$^{n.s}$
C_D	− 0.205***	− 0.152***	− 0.203***	− 0.155***	− 0.052***
C_E	− 0.035$^{n.s}$	− 0.089***	− 0.041*	− 0.097***	0.057***
C_F	0.223***	0.211***	0.226***	0.199***	0.028**
C_G	0.203***	0.198***	0.205***	0.192***	0.013$^{n.s}$
C_H	− 0.156***	− 0.148***	− 0.159***	− 0.146***	− 0.015$^{n.s}$

**p* value < 0.1, ***p* value < 0.05, ****p* value < 0.01, n.s. not statistically significant

Table 6 Results of the mediation test step 3

X	*M* : *TFD*		*M* : *FC*		*M* : *TVD*	
	b_{2X}	b_{2M}	b_{2X}	b_{2M}	b_{2X}	b_{2M}
C_A	− 1.116***	1.338***	− 0.995***	1.765***	− 1.106***	1.341***
C_B	− 0.961***	1.599***	− 1.014***	2.112***	0.971***	1.607***
C_C	0.804***	1.472***	0.720***	1.923***	0.800***	1.475***
C_D	0.638***	1.641***	0.624***	2.120***	0.635***	1.642***
C_E	n.r	n.r	− 0.340**	1.989***	− 0.455***	1.530***
C_F	1.211***	1.321***	1.134***	1.759***	1.206***	1.327***
C_G	0.068$^{n.s}$	1.530***	− 0.022$^{n.s}$	2.026***	0.064$^{n.s}$	1.534***
C_H	− 0.156$^{n.s}$	1.521***	− 0.096$^{n.s}$	2.006***	− 0.150$^{n.s}$	1.526***

X	*M* : *VC*		*M* : *AVD*	
	b_{2X}	b_{2M}	b_{2X}	b_{2M}
C_A	− 0.995***	1.902***	n.r	n.r
C_B	− 1.047***	2.292***	n.r	n.r
C_C	0.699***	2.064***	n.r	n.r
C_D	0.657***	2.295***	− 0.316**	0.547**
C_E	− 0.309**	2.137***	− 0.551***	0.590 **
C_F	1.129***	1.893***	1.495***	0.394*
C_G	− 0.040$^{n.s}$	2.184***	n.r	n.r
C_H	− 0.077$^{n.s}$	2.161***	n.r	n.r

**p* value < 0.1, ***p* value < 0.05, ****p* value < 0.01, *n.r.* not required,
n.s. not statistically significant

related to Y (e_{2Yij} is the error term). In Table 6, the results of "n.r." means "not required" because the corresponding variables in the previous step were already not statistically significant.

Therefore, according to the relationship between b_{0X} and b_{2X}, subjects' eye-movement measures partially mediated the influence of colors A ~ F on *Pscores* and completely mediated the influence of colors G and H on *Pscores*. H2 was supported.

The regression analysis results also indicated that when people were choosing among products of different colors, in contrast to common belief, if a customer looks at a product for a long time (higher TFD and FC) and looks it over several times (higher VC, TVD and AVD), these eye movements indicated that he/she does not truly like the color of the product.

Moderation test

Next, the moderation effect of Z between Y and X was tested. In this test, two steps with one regression equation were checked.

First, the intermediate coefficient XZ needed to be calculated with Eq. 6.

$$XZ_i = X_i \times Z_i, \tag{6}$$

where$i \in \{A, B, C, D, E, F, G, H\}$

Then, the results of the test regression equations needed to be checked with Eq. 7:

$$Y_{C_i} = a_{3i} + b_{3Xi}X + b_{3Zi}Z + b_{3XZi}XZ + e_{3Yi}, \tag{7}$$

where$i \in \{A, B, C, D, E, F, G, H\}$.

In this equation, the coefficient of XZ (b_{3XZ}) was used to infer moderation. As shown in Table 7, the results indicated that for half of the colors (A, C, G, H), a moderation effect existed (i.e., $b_{3XZ}$was significant), which means that XZ was related to Y (e_{3Yi} is the error term). H3 was partially supported.

The regression analysis results also indicated that the Japanese subjects had a higher evaluation when they were evaluating colors A (blue) and C (green) and that the Chinese subjects had a higher evaluation with colors G (yellow) and H (orange), but not the color red.

Influence path model

Finally, based on the related mediation and moderation test results, our influence path model was completed as shown in Fig. 4.

The model we identified is somewhat different from the universal model [15] that we used to design the experiment. What is consistent is that the subjects' eye-movement measures mediated the influence of all the specific colors on product evaluation. However, although subjects' cultural factors were related to eye movements when selecting products that was confirmed in H1, the test results showed that the role of cultural factors acts only as a moderating factor on the influence of specific colors to product evaluation.

Table 7 Results of the moderation test

X	b_{3X}	b_{3Z}	b_{3XZ}
C_A	− 1.241***	0.098$^{n.s}$	− 0.798**
C_B	− 0.783***	0.021$^{n.s}$	− 0.187$^{n.s}$
C_C	1.247***	0.166$^{n.s}$	− 1.347***
C_D	0.247$^{n.s}$	− 0.036$^{n.s}$	− 0.270$^{n.s}$
C_E	− 0.523***	− 0.017$^{n.s}$	0.742$^{n.s}$
C_F	1.538***	0.010$^{n.s}$	− 0.096$^{n.s}$
C_G	0.247$^{n.s}$	− 0.077$^{n.s}$	0.088*
C_H	− 0.732***	− 0.183$^{n.s}$	1.449***

*p value < 0.1, **p value < 0.05, ***p value < 0.01, *n.s.* not statistically significant

Moreover, for the specific colors A ~ H, their influence paths were all mediated by subjects' eye movements (completely or partly), which meant that the strict conclusion that "one's product selection process is only decided by his or her culture" cannot be drawn, and subjects' eye movements in response to visual stimuli are important in product evaluation.

Specifically, three different patterns existed in the influence paths.

First, for colors A (blue) and C (green), subjects' eye-movement measures partially mediated their influence on product evaluation, and cultural factors also played a moderating role in this influence path. This result indicated that for these colors' influence paths, the effect of cultural factors may be partly independent of the effect of eye movements. In other words, before viewing products, subjects may have some prejudgments about these colors. This finding is consistent with previous questionnaire research on the favorite colors of Japanese individuals [26].

Moreover, for colors G (yellow) and H (orange), subjects' eye-movement measures completely mediated their influence on product evaluation, and cultural factors also played a moderating role in this influence path. However, for these colors, the subjects' evaluation results were completely determined by their eye movements, which indicated that in these cases, a moderating effect of cultural factors did not exist on the path of "color evaluation" but existed on the path of "color eye movements evaluation".

Last, for colors B, D, E and F (light blue, light green, red and violet), subjects' eye-movement measures partially mediated the influence of the colors on product evaluation, but cultural factors did not play a moderating role in this influence path. This result indicated that for these colors, cultural factors did not affect an individual's decision regarding product evaluation. This finding was different from those in previous studies [9] because the influence of red (color E) on Chinese people was not detected in our analysis.

Conclusion

This paper provides an influence path model for specific colors on product evaluations in product color selection scenarios. An experiment was designed, and 40 Chinese and Japanese subjects' eye-movement measures, such as their fixation duration and fixation count for each color AOI, were collected by the eye-tracking device. Finally, a total of 2296 raw gaze samples were used for the analysis.

According to the method of difference analysis and the piecemeal approach for mediation and moderation tests, the experimental results showed that Chinese and Japanese people have significant differences in their eye-movement measures. Based on the mediation tests, with the exception of 2 measures (FFD and AFD), all eye-movement measures mediated the influence of specific colors on product evaluation. Moreover, cultural factors' moderate effect was also partly supported by moderation tests. The findings of this paper have important implications for user-centered product design and visual marketing management.

In this study, 40 young college students aged 18–22 years from China and Japan were invited to participate in the experiment and represented different cultures. For our future work, we will consider involving more groups, for example, to include subjects from more countries and increase the age span to represent more specific cultural factors.

Finally, we appreciate all the subjects who participated in the experiments.

Authors' contributions

BW—creating the research plan, designing and conducting the experiments, and writing the manuscript. YZ—providing support for experimental data analysis and evaluating the results. KY—providing support for experimental data collection and analysis. SN—evaluating and improving the experimental design and analysis methodology. QJ—evaluating and improving the research plan and analysis methodology and editing the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The data will be made available upon request.

Competing interests

The authors declare that they have no competing interests.

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