Design of Air Purifier Outlet Based on Eye Tracking Experiment and Semantic Differential Method

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Abstract: To explore the user's perception of the design of air purifier outlet, eye tracking experiment and semantic differential method were adopted. According to the outlet area of 25%, 50%, 75% and 100% of the side area and the position of the upper part, the middle part and the lower part of the side, 10 air purifier model pictures were made for experiments. By analyzing the hot zone maps and the scale scores, it is found that the samples that area accounts for 50% to 75%, with a high position are more attractive, and the evaluation of usability, preference and purchase intention are also better than other samples. Through the analysis of the results, we can grasp the design direction that meets the user's expectations and obtain the basic design principles of air purifier outlet.

1. Introduction

The use of air purifiers in life is becoming more and more common. It is not only to deal with smog and dusty weather, but also to clean the air that is not circulating indoors. It is an important part of ensuring healthy life. As competition intensifies, the air purifier market gradually shifts from enterprise-led to user-led [1], so exploring users' needs and attracting users' attention become the key. Based on the inference Kansei Engineering (KE) theory, Bai Renfei and Zhang Junxia [2] decomposed the design elements of the air purifier, established the semantic axis, and obtained the connection between the design elements and the perceptual appeals. Among the design elements of the air purifier, the air outlet is both an important factor in the formation of the air purifier and an indispensable part of its structure. In such products, the outlet has a key role and is a focus in terms of functionality and aesthetics. Therefore, the air purifier air outlet is taken as the research object, and the eye tracking technology and semantic differential method are used for research.

2. Eye Tracking Technology and Semantic Difference Method

Eye tracking technology is one of the ways to obtain physiological indicators of users. About 80% of information is obtained through vision, and eye tracking technology collects gaze points, which can obtain people's attention distribution of information [3]. In order to predict the users' aesthetic preferences and choice preferences, literatures [4,5] used eye tracking technology to detect the user's perception of the product. Semantic differential method is a usual approach to exploring users' Kansei needs [6-8]. By constructing image scale to quantify users' cognition, their attitudes towards product are obtained. Literatures [9,10] combine these two research methods to explore the users' perception of product design elements more comprehensively, which ensure the design direction. Literature [11] explored the objectivity of physiological measurements and psychometric measurements. In literature [12], the machine model was taken as an example, the rationality and effectiveness of eye tracking experiment method was compared with the consumer psychological experience based on the coupling theory of consumer psychological cognition and physiological response [13].

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3. Experimental Methods

To study the design characteristics of the air purifier outlet, users were tested on both physiological and psychological aspects. The physiological test used eye tracking technology to obtain gaze samples by tracking the eyes movement. The psychological test used semantic differential method and Likert scale to obtain the users' psychological assessment of different samples. Finally, results of two tests were combined to get the tendency of most people. The experimental process is shown in Fig. 1.

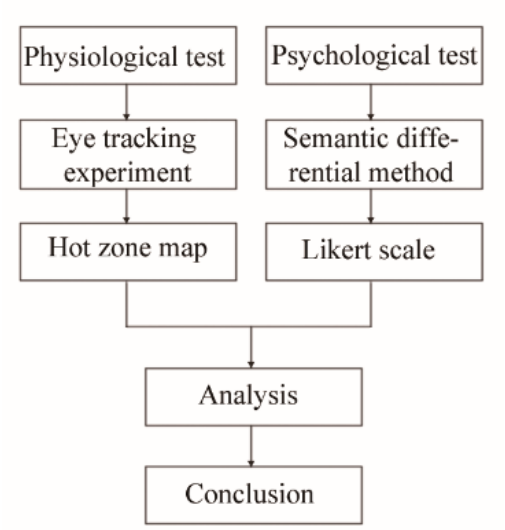


Figure 1. Experiment process

3.1. Participants.

A total of 47 participants participated in the experiment and questionnaires, all of whom were students of Beijing Forestry University, age between 18-30 years old. Myopia participants wore glasses. Naked eye vision or corrected vision was greater than 1.0. Each participant received 30-yuan remuneration at the end of the experiment. Three of them were not captured the eye movement during the fixed-point correction of the eye movement test and failed to perform the experiment.

3.2. Experimental Instruments.

Eye movement points were tracked using a Tobii Pro X2 eye tracker, and experiment was established by Tobii Studio software, which could also record test data. The eye tracker system component was divided into two parts, the eye tracker hardware and the external data processing module. The eye tracker hardware was portable and only 184mm in length, it was mounted on a laptop via an adsorption mount. Participants did not need to carry this device, which could reduce extra psychological and physical burden [14]. The external data processing module specialized in processing of eye tracking data, connecting the eye tracker hardware to the Tobii Studio software on the computer (using a USB interface, a power adapter was required). The eye tracking test instrument is shown in Fig. 2.

3.3. Experimental Pictures.

In order to eliminate the influence of other parts than the shape of the air purifier itself and the air outlet, the color and style of the experimental pictures were unified, and it was decided not to directly use market pictures, but to use sample pictures modeled by Rhino software and rendered by Keyshot software. Two indicators of air purifier outlet design, area percentage and position, were examined. The specific categories are shown in Table 1.

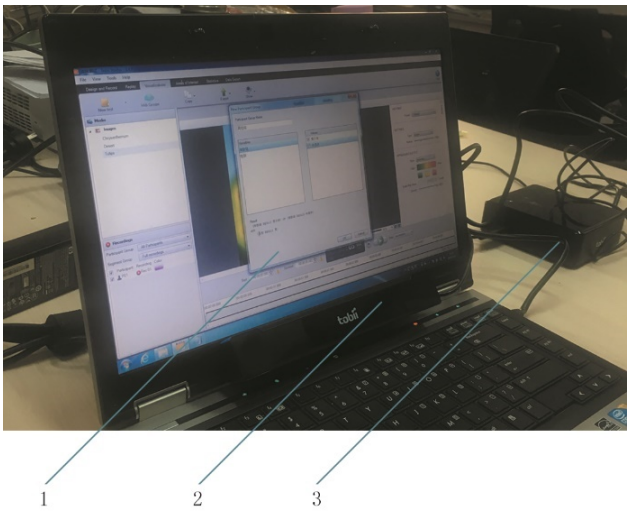
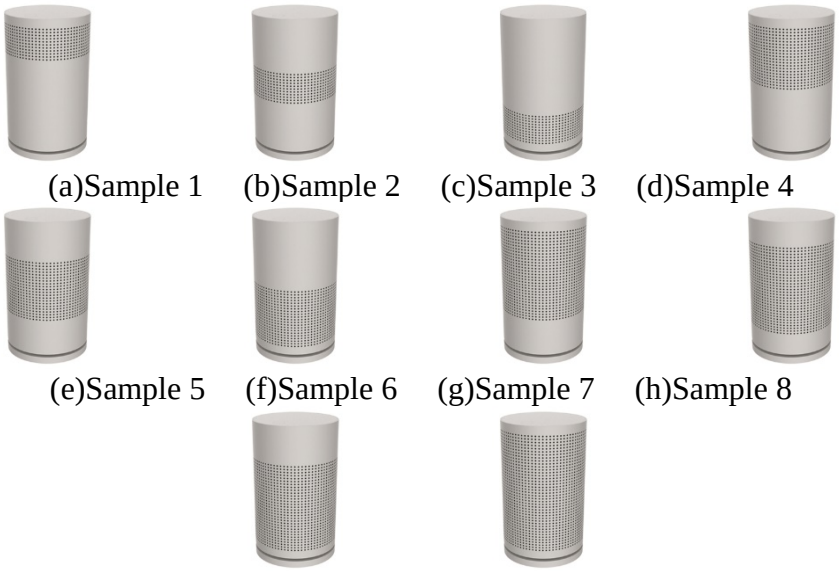


Figure 2. Eye tracking test instruments (1 Tobii Studio software interface;2 Eye trackter hardware;3 External data processing module)

Table 1 Categories of air purifier outlet

Design elements	Categories
Air outlet area percentage [%]	25, 50, 75, 100
Air outlet position	Upper, Middle, Lower

Ten cylindrical air purifier models were established. The percentage of the area of air outlet on surface was set to 25%, 50%, 75% and 100%. The position of air outlet was divided into three types: upper, middle and lower (area=100% outlet). Ten air purifier samples are shown in Fig. 3.



(a)Sample 1 (b)Sample 2 (c)Sample 3 (d)Sample 4

(e)Sample 5 (f)Sample 6 (g)Sample 7 (h)Sample 8

(e)Sample 5 (f)Sample 6

Figure 3. Air purifier samples

All experimental images were of uniform size and resolution (1600 × 900), the image of air purifier samples were in the center with the same position and size.

3.4. Experimental Process.

Experiment was conducted in a quiet room. After participants seated, their eyes position would be calibrated. Experimental task were then explained to participants. During experiment, the first picture is the experimental lead. Participants could start the experiment by themselves after reading. Ten air purifier pictures were played randomly, each playing for 10s. There would be a “+” centered white picture between each two experimental pictures, playing 5s, which was used to eliminate the

impression of previous picture. After completing experiment, the test data of more than 80% of the eye tracking samples were screened out, and a total of 28 valid data were obtained.

The semantic differential method questionnaire set three semantic scales of “availability”, “degree of preference” and “purchase intention”, each divided into 5 levels (2, 1, 0, -1, -2), and "0" represent a neutral attitude. The higher the positive score, the more positive the attitude, and the higher the absolute value of the negative score, the more negative the attitude. 44 valid questionnaires were collected. The quantitative representation is as shown in Table 2.

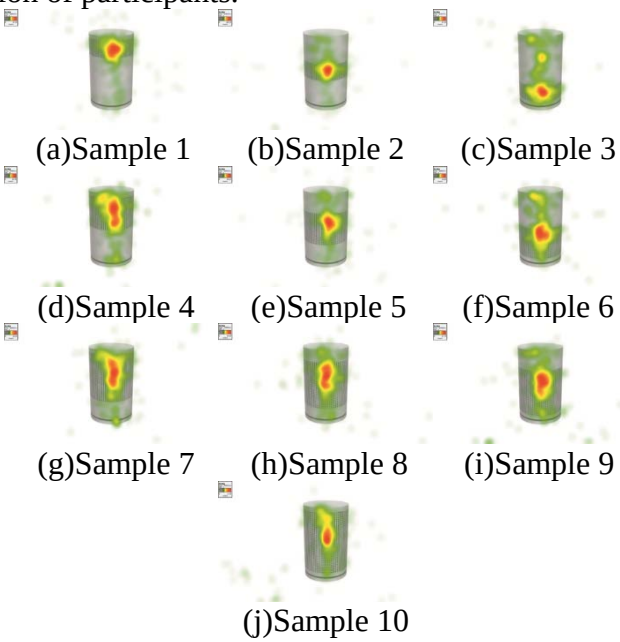
Table 2 Example of a semantic differential scale

Sample 5	
Availability	2 1 0 -1 -2
Degree of preference	2 1 0 -1 -2
Purchase intention	2 1 0 -1 -2

4. Results and Analysis

4.1. Analysis of Eye Tracking Experiment Results.

Organized the eye tracking experiment to get the hot zone map (Fig. 4). The area from green to red in the figure is the area at which participants looked. The color redder, the denser the gaze point. It showed the higher attention of participants.



(a)Sample 1 (b)Sample 2 (c)Sample 3

(d)Sample 4 (e)Sample 5 (f)Sample 6

(g)Sample 7 (h)Sample 8 (i)Sample 9

(j)Sample 10

Figure 4. Hot zone map of eye tracking experiment

In the terms of the area of air outlet, the larger the area, the larger the hot zone. But when the area reached 100%, the hot zone shrunk. It showed that when the area of air outlet increased to 75%, participants’ attention would be concentrated as much as possible in the larger outlet. However, when air outlet occupied the whole surface, participants no longer pay attention to the area of the air outlet.

In the terms of the position of air outlet, in the same area group, samples 1, 4 and 7 which were in the upper of the air purifier had a larger hot zone area than the samples 2,3, samples 5,6, and samples 8,9 in the same area group. The samples 3, 6, and 9 in the lower position of air purifier and the sample 10 in the area 100% had a part of the fixation points distributed to a higher position. It showed that

participants tend to distract a part of attention to the upper part of air purifier when observing the samples. And it was more attractive when the air outlet was placed on the upper part of air purifier.

4.2. Analysis of Semantic Differential Questionnaire Results.

The scores of the semantic differential scale questionnaire were collated. The weighted average of each score was calculated according to Eq. 1. The results are shown in Table 3. The comparison of the three indicators for each sample is shown in Fig. 5. The ranking of the scores of the samples in each indicator and the ranking of the comprehensive three indicators are shown in Table 4.

$$x = \frac{1}{n}\sum_{k=1}^{n} x_k f_k \ . \tag{1}$$

x——The score given by participants;
f——Occurrences number of each point value;
n——Number of participants.

Table 3 Air purifier outlet sample scores

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Availa-bility	0.386	-0.432	-0.409	1.045	0.841	0.091	1.023	0.795	0.614	0.727
Degree of prefere-nce	0.409	-0.364	-0.455	0.705	0.636	-0.273	0.477	0.273	0.000	-0.409
Purcha-se Intenti-on	0.227	-0.727	-0.773	0.523	0.568	-0.182	0.568	0.205	0.045	-0.455

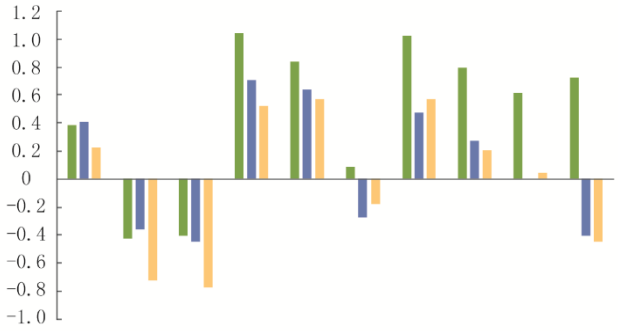


Figure 5. Comparison of three indicators for each sample (green= availability, blue= degree of preference, orange= purchase intention)

Table 4 Ranking of sample scores in each indicator and overall ranking

	Availability	Degree of preference	Purchase Intention	Overall Ranking
Sample1	7	4	4	5
Sample2	10	8	9	9
Sample3	9	10	10	10
Sample4	1	1	3	1
Sample5	3	2	1	2
Sample6	8	7	7	7
Sample7	2	3	1	2
Sample8	4	5	5	4
Sample9	6	6	6	6
Sample10	5	9	8	7

The top three samples for usability were samples 4, 7 and 5, and the last three were samples 6, 3, and 2. The best evaluation was 50%-upper (air outlet area percentage= 50%, position= upper. Following expressions have the same meaning), the worst was 25%-middle. As can be seen from the

figure, since the area percentage of the air outlet reached 50%, the evaluation of the availability had been significantly improved. In the same area percentage group, the higher the outlet position, the better the usability evaluation. When the air outlet was in the upper and middle positions, the usability evaluation peak when the area percentage was 50%. When the area percentage was 75%, the usability evaluation was the highest. When the area percentage was 100%, although the ventilation was the largest, the usability evaluation was not prominent. When the air outlet area was too small, the usability evaluation was relatively negative.

The top three samples for degree of preference were sample 4, 5, and 7, and the last three were samples 2, 10, and 3. The best evaluation was 50%-upper, and the worst was 25%-lower. The figure showed that in the same area percentage group, the higher the position of the air outlet, the better the evaluation of the degree of preference. When the air outlet was in the upper and middle positions with 50% of area, participants' preference evaluation was significantly better than other form of area percentage. When the outlet was at the lower position or the area percentage was 100%, people generally did not like this form. The preference was negative.

The top three samples of purchase intention were samples 5, 7, and 4. The last three were samples 10, 2, and 3. The best evaluation was 50%-middle, and the worst was 25%-lower. From the figure, the samples with negative scores were samples 2, 3, 6, and 10. Except sample 10(area percentage= 100%), air outlets of the other samples were in the middle or lower position. Although the score of sample 9 (area percentage= 75%) was positive, it was only 0.045, which ranked bottom except for the four samples with the negative scores. This showed that when the position of the air outlet was relatively low, regardless of the area, the purchase intention was generally low. When the area percentage was 75% and the position of the outlet was in the upper position, it was the most popular. When the area percentage was 50% and the outlet was in the upper or middle, people would be more willing to buy.

In overall ranking, the top three samples were 4, 5 and 7, and the last three are samples 6, 10 (score tied), 2, and 3. Overall, when the area percentage of the outlet was 50% and the position was in the top part, people's attitude to three indicators was relatively positive. When the outlet area percentage was 25% and the position was in the middle or lower parts, the scores of the three indicators were all negative, indicating that people generally had a negative attitude toward the small-area and low-position outlets. When the air outlet area percentage reached 100%, the evaluation of the availability and the other two indicators had a quite gap. The usability evaluation was medium, but people had low degree of preference and purchase intention to this form.

The results of the eye tracking experiment had a good consistency with the scale questionnaire. The hot zone plot of the eye tracking experiment showed that the sample, whose area percentage of air outlet was between 50% and 75% and position was relatively up, was more attractive. The results of the questionnaire showed that the sample which was on the top and with the 50% area of the outlet earns the highest scores in three indicators, which respectively were the usability, the degree of preference and the purchase intention.

5. Conclusion

5.1. Air Purifier Outlet Design Principles.

According to the above analysis, the uses' attitude towards the design of the air purifier air outlet can be obtained. Users preferred the outlet in the upper position of air purifier area, which is conducive to the circulation of fresh air, and on the other hand fit the distraction situation of the attention of people when they observe the product. For the area of the air outlet, the proportion in the range between 50% with 75% fit users' preference better. Although the larger the outlet, the greater the ventilation, the better the effect as an air purifier. But people's preference of the outlet area does not match this rule. It will be fatigued both visually and psychologically, when the area of the air outlet is too large.

5.2. Complementary Relationship between Eye Tracking Experiment and Semantic Differential Method.

The focus of the eye tracking experiment and the semantic differential method are different. The eye tracking experiment measures the human physiological response and captures the subconscious data. For example, when looking at the experimental picture, participants would unconsciously distract a part of the attention to the upper of the purifier, which was difficult to reflect by the scale score. Semantic differential method measures people's psychological cognition. The test result is the answer after thinking. For example, the participants scores of degree of preference for most of the samples were greater than the purchase intention. But the preference for sample 7 (75%-upper) was less than the purchase intention. The purchase intention and availability ranked relatively in the top in 10 samples. Even if they did not like it very much, people were more willing to buy because of its good usability. The eye tracking experiment and the semantic differential method have mutually validated parts on the whole, but have their own characteristics in the details. The two methods are often used together. It can be more comprehensively to analyze the problem when grasping the complementary characteristics of the two.

6. Prospect

After a preliminary discussion, some inspirations from the design elements of the air purifier can be derived. Through the test to understand the users' needs and preferences and to obtain design principles of the air purifier air outlet, which can bring better use and aesthetic experience to users. But there are still much to improve. In the eye tracking experiment, a total of 44 participants carried out the experiment. However, only 28 participants' gaze samples reached 80%, which was regarded as valid data. It was likely because that too more samples and the long test time created a burden. And some participants could not fully concentrate on the experiment. This point may be discussed in more depth to know how to strike a balance between the sample quantity and the fatigue of subjects.

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