RESEARCH ON HUMIDIFIER DESIGN BASED ON EYE-TRACKING TECHNOLOGY

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This paper aims to explore the perceptual needs of target users for product design and help designers to accurately understand the user's implicit intentions. Firstly, based on the theory of cognitive psychology, a free-observation observation sample and a task-oriented experimental sample with animal image as a variable are produced. Then, eye movement data of the subjects are collected by the eye movement instrument. According to the eye movement data, the sample which accords with the subject's image cognition is determined; Thirdly, taking the sample as an example, combined with the principle of bionics, extracting its key features, constructing a mapping model between image cognition samples and design elements, and giving a design plan. Finally, taking this design and other similar products as samples, the eye movement data of the subjects were collected as the perceptual evaluation index. The results showed that the subject's perceptual cognition of the humidifier was consistent with their memory perception of the animal. And the emotional evaluation index showed that the product designed according to the experimental results received the highest attention. It indicates that the method of using eye-tracking technology to engage target users participate in the design can help designers work out products with high emotional matching degree with users, and in a certain extent to improve the success rate of products.

Keywords: Industrial design; Eye-tracking technology; Humidifier; Modelling design

1. Introduction

With the development of industrial design, the expectation of users for products is no longer just a functional "entity". In the analysis and expression of instincts, behaviors, and reflections, the emotional attributes contained in products become the key factors that drive consumer behavior [1][2][3]. Product modeling is the first medium to carry the externalization of consumers' emotional cognition. However, the relationship between product modeling elements and product emotional attributes belongs to the "black box" model [4], and its cognitive

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evaluation is generally based on psychological experience. However, it is greatly affected by the external environment and emotions, which cannot accurately describe the psychological state of consumers. The emergence of eye-tracking technology is exactly the bridge between the two. Studies have shown that at least 80% of external information is visually entered into the human central nervous system. The movement of the eyeball is the external manifestation of the brain's processing of information [5]. Eye tracking technology uses eye tracker to track the eye movement of the subject, and explores the physiological emotions of the user when observing the experimental sample, and externalizes it. Through the quantitative analysis of the data, the potential cognitive process of the subjects is inspected and the ecological validity of the research is enhanced [6,7].

At present, eye tracking technology is widely used in the fields of human-computer interaction, design evaluation, and usability evaluation. For example: Guan Sisi [8] used this technology to study the man-machine interface of the vending machine from the aspect of the layout rationality; Zhong Qi [9] et al. established a design selection model for tractor modeling based on eye movement data; In order to improve the experience of the airline's official website; Jin Huibin [10] and others used the eye tracker to evaluate the website's usability.

Some researchers have used eye movement experiments in the extraction of design genes. For example: Zhang Yunfan [11] used the eye movement experiment and fuzzy evaluation method to study the design genes of the pottery in the Northern Song Dynasty; Wu Xindy and others [12] extracted the culture DNA of the Dong Drum Tower based on eye movement technology , improve the expression of modeling DNA in the Dong Drum Tower culture through reorganization, and apply it to the innovative design of earring products to provide references of the inheritance, development and innovative application for the Dong culture; From the user's point of view, Wang zhenya et al. [13] conducted extraction and cognitive research on automobile modeling features based on eye movement tracking technology. The eye movement data comes from the real situation, with the characteristics of visualization, quantitative precision and more stereoscopic and accurate understanding of the user's implicit intention from multiple dimensions such as fixation point and fixation time [14]. What the designer needs in the initial stage of design is precisely to grasp the user's needs. In this paper, the eye movement experiment is used in the stage of concept generation and user evaluation to determine the product modeling image, through the eye movement data to determine the product modeling image, establish a mapping model between product image and modeling design elements, more realistically restore the user's implicit cognition, meet the user's emotional needs, and improve the success rate of the product.

2. Eye-tracking Test

2.1 Test purposes

The purpose of this paper is to mine the perceptual demand of the target user for the product, so the humidifier, which has a high perceptual demand, is selected as the design object in the eye movement test. Based on the physiological principle, the eye movement data of the subjects were collected by SMI REDn Scientific eye movement instrument (sampling rate: 30 Hz). BeGaze3.6 software was used to objectively analyze the data to determine the test samples that best matched the subjects' cognition of humidifier image.

2.2 Test sample

2.2.1 Free observation sample

According to cognitive psychology theory, cognitive resources can focus on a small part of psychological representation in a short period of time, called short-term memory. It enhances the short-lived understanding of stimulus information through visual coding and auditory coding. Based on the principle of short-term memory, a video (Fig. 1) of the working and using scenes of the humidifier was made for 30 seconds, which was used as the free observation experiment material (i.e. stimulus information) to strengthen the cognition of the humidifier in the mind of the subjects.
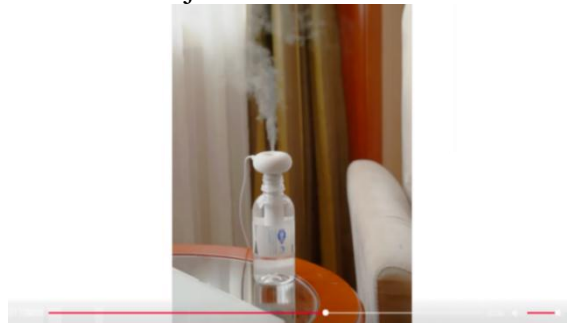

Fig.1 Experimental material for free observation

2.2.2 Task test sample

KJ research method was adopted to combine the functional requirements of the humidifier -- spray and humidification -- and to select the functional images matching the humidifier. For example, the subjects could make associations based on previous experience and arouse emotional resonance of biological prototypes -- aquatic animals and amphibians, etc. as samples to form a preliminary sample database (Fig.2). In turn, a panel discussion was held with the designer as the main

body, and eight samples, such as elephants and dolphins, were determined to make a task test sample (Fig. 3).
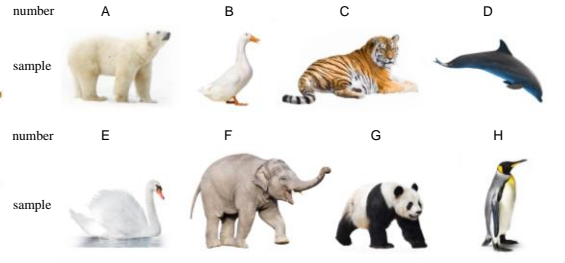

Fig.2 Preliminary sample library

Fig.3 Task-based experiment samples

2.2.3 Subject selection

Twenty subjects were selected from the study, aged 22-40 years, and 10 males and 10 females. The subjects all have high school education or above and can understand the test requirements; And the subjects have experience in the use of humidifiers, have a certain knowledge of the function of the humidifier and knowledge reserves to improve the reliability of the test. In addition, all subjects were free from color blindness or color weakness, and their visual acuity (including corrected visual acuity) was 1.0 or more.

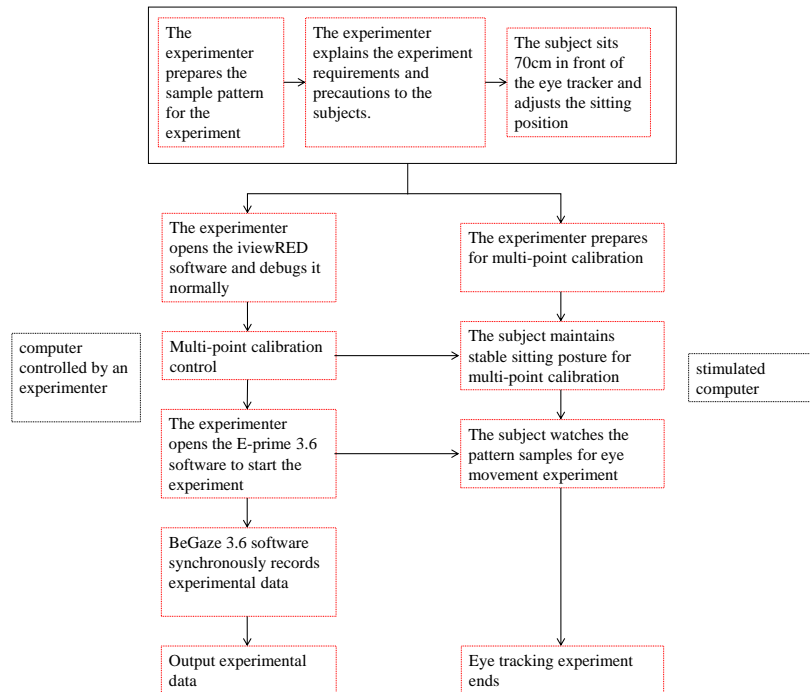### 2.4 Experimental procedure

Fig 4: Flow chart of eye-tracking technology experiment

The test was carried out in the eye tracking laboratory, and the privacy was good. The subjects entered the laboratory in turn, ensuring that each subject saw the test sample for the first time to improved the test accuracy. The test procedure is as follows (Fig. 4):

2.5 Test data and analysis

(1) In order to express the test data more clearly, the meaning of the test indicators is explained, as shown in table 1:

Table 1

Eye tracking experimental indicators

Eye tracking indicators	Indicator meaning
Area Of Interest (AOI)	Areas interested by researchers
Fixation tracker	The fixation positions are connected with lines
First fixation	Time when the subject's sight falls on the first fixation point in the AOI area
Dwell time	The total fixation time when the subject's sight falls in the AOI area
Fixation count	Number of fixation points when the subject's sight falls in the AOI area
Average fixation	The dwell time when the subject's sight falls in the AOI area divided by the number of fixation points

(2) Hot spot diagram

The hot spot diagram shows the fixation time of the subjects in color. Red represents the longest fixation time, followed by yellow, and green represents the shortest fixation time. The primary color of the sample indicates that the subjects do not pay attention to this area.
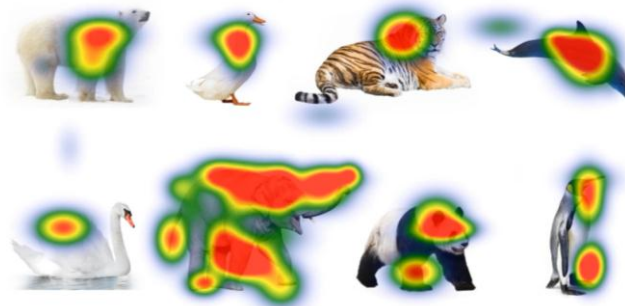

Fig.5 Sample hot spot diagram

Figure 5 is a hot spot diagram of the test sample, from which we can see that sample F (elephant) has the largest red area, that is, the highest degree of attention, followed by sample D (dolphin).The hot spot diagram can intuitively show the degree of attention of the sample, but it is difficult to make a specific judgment for

the areas of similar concern, so it is necessary to export the specific experimental data of the region of interest (AOI) for analysis.

(3) Area of interest (AOI) data analysis

The area of interest is where the experimenter divides the sample into different areas according to the purpose of the study. An eye tracker was used to measure and record the fixation duration and number of fixation points of the subjects when they gazed at each area. Through the analysis of the data, the visual movement rule of the subjects was found. Figure 6 is the data graph of the region of interest when one subject is watching the test samples, and table 2 is the average data of the 20 subjects watching the test samples.

Fig.6 AOI region data graph

Table 2

AOI region data

Sample number	First fixation/ms	Fixation length/ms	Fixation count	Average fixation time/ms	Fixation time ratio
A	2099.9	4166.49	4	1016.6	3.3%
B	1199.9	7732.7	6	1277.7	6.1%
C	1066.6	5399.7	4	1341.6	4.2%
D	2466.4	25497.8	11	2287.7	20%
E	4499.6	7132.8	2	3566.4	5.6%
F	600	51928.6	23	2241.8	40.7%
G	466.7	11965.6	4	2983.1	9.4%
H	4799.5	9799.1	4	2433.2	7.7%

According to Godijn et al [15]. Human eye movement control is an "integration-competition" model, including exogenous control and endogenous control, which is the integration of attention and eye movement. The eye movement of the subjects were inextricably linked to the attention and cognitive processes, that is, the information perceived by the subject's eye movement was actually what the subject "want to see" or "what they saw" [16]. From the data in Table 2, the subjects

observed the maximum number of gaze points in sample F, followed by sample D. High-frequency gaze helps to deep-process visual information and stimulate brain information to make decisions [6]. It shows that the subject's perceptual cognition of the humidifier is consistent with the memory perception of the animal - the humidifier spray function is similar to the elephant water spray and dolphin jet skills. And from the hot spot diagram of Figure 5, it can be seen that the area where the subject's line of sight is most concentrated is the position of the elephant trunk and dolphin blowhole, which can be understood as "humidifier - the subject - sample F, D" Emotional matching is achieved.
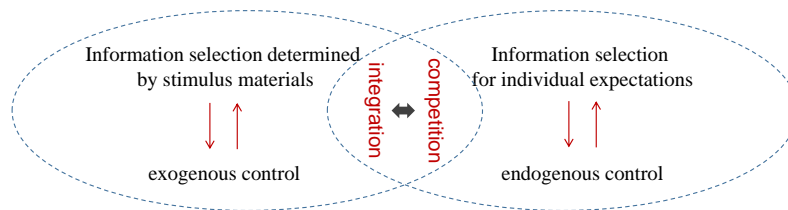

Fig.7 "Integration-competition" model

Based on the above experimental results and the designer's personal experience, sample F (elephant) was selected as the image cognition sample to carry out the design practice of humidifier.

3. Humidifier design

The image design of the humidifier based on the sample F is actually the image bionic design with the sample F as the prototype. Bionic is divided into overall bionic and partial bionic. The overall bionics is an overall imitation of the biomimetic form, focusing on the integrity of the form, giving consumers an intuitive feeling; Partial bionics is the imitation of the local form of bionic creatures [17].According to Gestalt psychology theory, the whole of things is greater than the local, the nature of the overall decision part, People's cognition of things is also from the whole to the part [18]. The design of the humidifier is based on the elephant's overall image bionics.

3.1 Bionic object feature extraction

3.1.1 Bionic object image feature extraction

In the image feature extraction stage, the typical features of the bionic object are applied to the feature parts of the product design, and the reasonable matching of the bionic objects is ensured from the visual cognition. The elephant is large and sturdy and simple in structure. It is typically characterized by an extremely flexible and flexible long nose. Its water-repellent and water-spraying functions are highly matched to the humidifier function image. Table 3 shows the mapping relationship

model between the elephant's external features and the modeling design elements of the humidifier.

Table 3

Mapping model of elephant shape features and humidifier modeling design elements

shape feature	Image expression	Application site
nose	Water absorption, water spray	Fog
body	Huge, honest, cute	Water tank
leg	Stout, strong ,stable	Water tank decoration
ear	Huge, heavy	Body decoration
tail	flexible	Body decoration

3.1.2 Bionic object morphological feature extraction

Product bionics is not a simple imitation of bionic objects, but to refine its essential features through simplification and abstraction under the premise of grasping the "demeanor" of bionic objects. According to the basic characteristics of the humidifier, functional requirements and psychological needs of the target users, the elephant samples are vectorized to make the modeling features more clear. Figure 8 is the real picture of the sample F elephant and the processed vector picture.
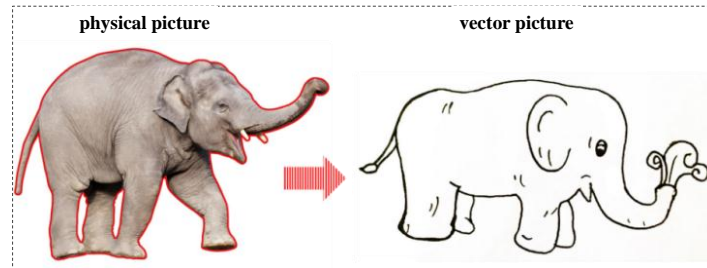

Fig.8 Elephant photos and vector maps

3.2 Application of bionic object features in humidifier design

Image bionics is a design method that balances the relationship between function and form in product design on the basis of satisfying the perceptual needs of target users. Therefore, the bionic design can be expressed by three levels of emotional design: instinct level, behavior level, and reflection level(Fig.9)[3].
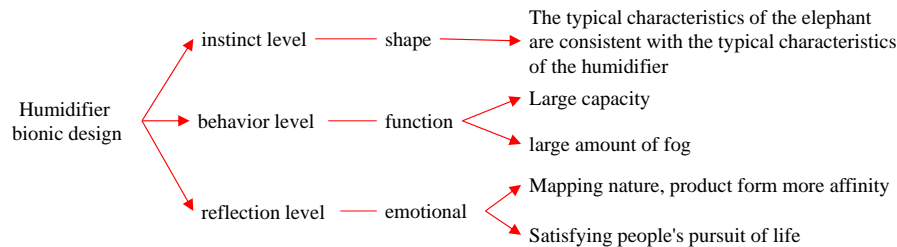

Fig.9 Bionic design emotional hierarchy model

The instinctive level of design focuses on the sensory level of the product's shape, color, material, etc., is the first impression consumers face in the product. At this level, the typical characteristics of the elephant's nose spray are consistent with the typical characteristics of the humidifier's fog; The behavior level design focuses on product function, usability and ease of use. The elephant's huge body is used as the humidifier's water tank, and the long nose makes the fog to meet the basic needs of consumers for the humidifier function; Reflective level design focuses on the emotional needs of products for consumers. Due to the natural attributes of the bionic object, the bionic design can more or less reflect the nature, make the product form more approachable, and meet the psychological needs of consumers at a higher level [19].

3.3 Humidifier design display

According to the research of 3.1 and 3.2, combined with the functional requirements of the humidifier, determine the shape of each part, and sketch and product modeling (Fig. 10, Fig. 11).

The body of the elephant acts as a water tank for the humidifier.

The elephant trunk acts as a venting port, which matches the imagery perception of the humidifier with the elephant trunk.

In addition to retaining the elephant's own elegant "elephant ash", the color adds a rich candy color to provide consumers with more choices.
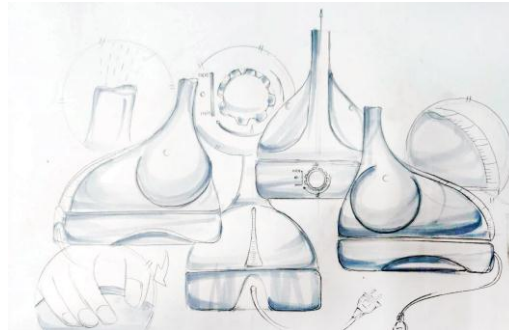

Fig.10 Humidifier design hand drawing

Fig.11 Humidifier design modeling diagram

4. Design evaluation

Design evaluation is an indispensable step in the "user-centric" design. In the evaluation, different evaluators should be selected according to the evaluation objectives. Combined with literature analysis, the "product evaluator selection model" (Fig. 12) is proposed [20]. Ten industrial designers and target users were selected as the subjects, and the eye movement test method was used for product evaluation. Search "humidifier" on taobao.com and sort the results according to "sales volume". Select the top 5 places and the products designed by this experiment as test samples (Fig. 13).
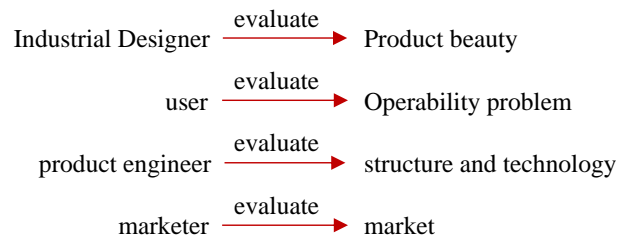

Fig.12 Product evaluator selection model
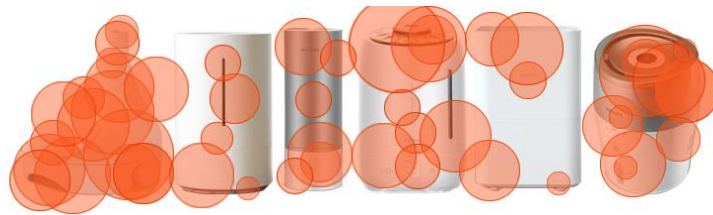

Fig.13 Evaluation of experimental samples

Fig.14 Evaluation of experimental trajectories

The eye movement trajectory of the evaluation test is shown in figure 14.The red circle represents the fixation point, the size of the circle represents the duration of the fixation point. As can be seen from the figure, the number of fixation points of the products in this experiment is significantly more than that of other test samples. According to the "competition-integration" model in figure 6, the more fixation points there are, the longer the duration of fixation indicates that the sample is what the subject "wants to see", which is in line with the subject's cognition and emotional needs.

5. Conclusion

In this paper, the humidifier design is taken as an example. The eye tracking technology is used to explore the user's implicit intention. Through the visual analysis of the eye movement data of the subject, the product modeling image is obtained, and the mapping model between the product modeling image and the design element is established. Explore the product design method based on physiological emotions. The main conclusions are as follows:

The eye movement data showed that the subject's perceptual cognition was highly consistent with the previous memory cognition, indicating that the subject's psychological perception and physiological response had a corresponding coupling relationship.

In the design, the product cognition image (bionic object characteristics) is basically consistent with the product function image, which can improve the emotional matching between the product and the user.

This paper proposes a selection model of product evaluator, according to which the subjects are selected, and the perceptual evaluation is carried out by eye movement test, which can effectively reduce the subjectivity of the evaluation results.

Eye tracking technology provides new ideas for product design and target users to participate in research and development. However, due to objective conditions, especially the limitations of the test equipment, the number of subjects and the sample selection were not accurate enough to cover all valid samples. In the future, we will combine more design examples to expand the depth and breadth of research in order to restore user perception more realistically.

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