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Aided Product Modeling Design Based on Virtual Reality Technology

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Abstract: *With the development of science and technology and the complexity of design objects, the requirements for product modeling design are getting higher and higher. How to design products in a targeted manner to meet the needs of consumers has become a key issue for enterprises. In order to improve the efficiency of product design, this article has carried out a research on the design of a new refrigerator product that a company plans to launch based on virtual reality technology. First, based on the conventional new product launch process, virtual reality technology is incorporated in the two links of market research and prototype testing. The virtual research client was tested after research and development. The average score was 9.32 for stability, 9 for ease of operation, and 8.86 for experience comfort. After optimizing the comfort level, a virtual survey was randomly launched on the home appliance shopping website. Analyze the general situation of 1258 users, the factors that affect refrigerator buying behavior, and the acceptable price of refrigerators. Among the 1,258 users who participated in the virtual survey, the male to female ratio was 0.9:1, and the age was mainly between 25 and 35. The number of people with high school education was the largest, accounting for 39.6%, 46% of users believe that price is the primary factor they consider when buying a refrigerator, and the generally accepted range is around 3,000 yuan. After obtaining sufficient demand and market information, develop new products, build a virtual design database, perform scene modeling, texture mapping, and achieve interactive effects. Of the 739 users who participated in the virtual experience, only 526 of them thought it was more comfortable during the experience. Therefore, it is necessary to improve the comfort during the experience. Only 59 people are very satisfied with the appearance of the refrigerator, and the appearance of the new refrigerator should be adjusted in time to meet market demand. The user's purchase intention ratio for the three refrigerators A, B and C is 1:3:1.6, and production can be arranged according to this ratio. The total cost of virtual design is 154,800 yuan less than traditional design, and the total time is 23 days less. This shows that product modeling design based on virtual reality technology can save costs and improve efficiency, and it is worth promoting.*

Keywords: *Virtual Reality Technology, Product Modeling Design, Virtual Design, Market Research, Virtual Experience Testing*

1. Introduction

1.1 Background Significance

Since the birth of virtual reality technology, its figure has been active in various fields, such as education, tourism and games [1]. People gradually accepted virtual reality technology and gradually applied it to the production industry. Product modeling design is a complex and indeterminate process, which not only places high design requirements on designers, but also requires designers to have keen observation and analysis capabilities. Because a good product must be born on the basis of market demand analysis and feedback [2]. The use of virtual reality technology enables virtual modeling of products before the production of actual products to obtain feedback information. It can be said that this technology has had a huge impact on product design. Therefore, the research on the application of virtual reality technology in product design is of great significance.

1.2 Related Work

Virtual reality technology is widely used in many fields, so related research results are also

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emerging in endlessly. Zhu W evaluated the virtual tourism simulation and experience system based on neural network, and established a virtual tourism evaluation model through a large number of questionnaire surveys and collection of relevant data. He also verified the model with Huangshan, Taishan, Forbidden City and Wuzhen as research objects [3]. Maples-Keller J L reviewed the development history of virtual reality technology and its application in psychiatric treatment, based on the empirical evidence of virtual reality treatment, and the benefits of virtual reality technology for psychiatric research and treatment [4]. Although their research data samples are large, the methods used in the analysis of the data can cause errors in the results. Product modeling design has always been the focus of attention in the design field. Tang D obtains and tracks product design knowledge through single-domain demand-side management and multi-domain demand-side management, and introduces a design knowledge management system based on demand-side management [5]. Labat K L analyzed the product design process used in related fields, proposed a general structure that links these working methods, and demonstrated how university design teams can use this structure to cooperate with industrial customers [6]. Their research has provided theoretical support for product styling design, but they have not incorporated the latest technology.

1.3 Innovative Points in this Paper

In order to reduce the cost of product styling design, obtain timely feedback information, improve design efficiency, and design high-quality products that cater to market needs, this article conducts in-depth research on product styling design based on virtual reality technology. The innovations of this research are as follows: (1) Use virtual reality technology in market research to create a virtual research client, evaluate it and optimize it based on feedback, and conduct virtual research on website users. (2) Construct a virtual scene in the prototype test, invite users to have a virtual experience, and improve the product based on user feedback on the product. (3) Compare the cost and time spent in the three stages of research, development and testing between virtual design and traditional design. It is found that virtual design can save total cost and shorten total time.

2. Virtual Reality Technology and Product Design

2.1 Virtual Reality Technology

(1) Characteristics of virtual reality technology

Virtual reality technology integrates multiple disciplines such as computer graphics, electronic technology and multimedia technology, so it is very characteristic. The three most typical characteristics of virtual reality technology include immersion, interactivity and imagination [7]. Virtual reality relies on digital technology to bring people the most realistic experience. Sensory immersion is the most important aspect of design. Computer technology simulates the virtual environment, presents an ideal world picture, combined with the stereo sound function, stimulates the senses with the help of the tactile sensation of the simulator, and strives to change the taste of the actual scene by combining the scent perception with the virtual environment.

Virtual reality technology takes device interaction as a key point and pushes human-computer interaction to a new level [8]. The technology will use the machine to improve the audience's experience of the virtual environment. This is one of the most important functions of virtual reality technology in display functions. The interactivity of virtual reality technology is the bridge between the optimized device and the user's feelings.

The audience is immersed in the virtual system, and the brain extracts new knowledge by processing the information of the virtual scene, thereby enhancing the audience's perceptual and rational understanding. Imagination will allow the audience to develop new relevance related to the product, and then achieve the effect of inspiration and progress, and change the way people think.

(2) Types of virtual reality technology

Virtual realization technology includes all related technologies and methods with natural simulation and lifelike experience [9]. According to the different forms of users participating in the virtual reality system and the degree of immersion, virtual reality technology can be divided into distributed, augmented reality, immersive, and desktop virtual reality [10].

In a distributed virtual reality system, multiple users are connected through a computer network to

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experience virtual experiences together to achieve the purpose of collaborative work. The augmented reality virtual reality system can use virtual reality technology to simulate the real world and enhance participants' experience of the real environment.

Immersive virtual reality systems generally provide a fully immersive experience. Desktop virtual reality uses personal computers and low-end workstations for simulation, uses the computer screen as a window for users to observe the virtual world, and realizes the interaction with the virtual reality world through various input devices [11].

(3) Virtual reality and aesthetics

For the science and technology of virtual reality, technology itself has no concept of beauty. When technology and reality are combined, there will be beautiful theories. The beauty of the virtual world can be divided into two categories: natural beauty and creative beauty. The natural beauty of the virtual world is to restore the beauty of the real world and reflect it on the computer in a digital mode. Natural beauty often cannot fully satisfy people's aesthetic needs. In order to achieve a higher spiritual pursuit, new aesthetic standards and new aesthetic concepts have been created. Creating beauty is the benchmark of beauty formed according to specific natural laws and lifestyle habits.

Product design belongs to the creative beauty in aesthetic theory. Not just a combination of several parts, the function and existence of the product itself is a kind of social functional beauty [12]. The creation of products improves people's living standards and becomes a social attribute of beauty. In virtual aesthetics, creating beauty is an important part. The existence form of virtual aesthetics is works, and works can be divided into the material level of external factors and the spiritual level of internal factors.

The aesthetic elements in virtual reality mainly come from the author's life experience, artistic conception and intentional materialization. Emotional expression is an essential element for constructing a more realistic virtual world, and aesthetic creation is an important part of virtual reality [13]. Life experience is the basis for constructing a virtual reality environment, and artistic conception is an important part of constructing virtual aesthetics. Intentional materialization displays design concepts in the form of design language to achieve a perfect interpretation of virtual aesthetics.

2.2 Product Modeling Elements

(1) The composition of product modeling elements

Product modeling is a free-form surface problem that belongs to the category of visual art design. The shapes of points, lines and surfaces are the basic elements of its modeling. Product styling is the visual and concrete expression of product design, as well as the expression of things under certain conditions, and is the most direct styling language [14]. The product cannot be independent of the purpose of use, use environment, target population, use conditions, use time, and actions. The so-called product styling is to combine the above-mentioned aspects with functions, materials and system elements to form the "special trend" of the product. In addition to the overall visual image, the perceptual image of the product shape is also provided to people.

Product modeling elements mainly include the purpose and basic functions of the product, the basic size and size of the modeling basis, environment and use background, materials and colors used, modeling characteristics, storage methods, semantics and sensory characteristics, use time and frequency[15] . The styling design of a product can bring users in a predictable way, which expresses not only visual sensory experience, but also cultural communication, value level and personality pursuit [16].

The elements of product modeling can be divided into two types: formal attributes and intuitive attributes [17]. The form attributes include the appearance, color, volume and material of the product. The intuitive attributes of product styling elements include practicality, durability and convenience.

(2) Product modeling parameterization and data processing

According to product modeling characteristics, parameterized calculations can be performed. Select the appropriate parameterization method and describe it digitally, and quantify the design parameters of the sample modeling. This method provides a basis for quantitative or qualitative analysis for product modeling design. The curve control method can be used to study the parameterization of samples. The parameterization of the curve control method uses the key points of the actual research product to control the modeling curve, and the coordinate value of each key point is determined for

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parameterization [18]. The difference of the coordinates of each point of the Bezier curve is shown in Formula 1:

$$P(x)=\sum_{i=0}^{n}P_iB_{i,n}(x),\quad x\in[0,1] \tag{1}$$

Among them, P_i is the i-th vertex of the characteristic polygon forming the Bezier curve, and $B_{i,n}(x)$ is the sub-Bernstein function:

$$B_{i,n}(x)=\frac{n!}{i!(n-1)!}x^i(1-x)^{n-i},i=0,1,,2,...,n \tag{2}$$

When processing data, firstly discretize and reduce the dimension of characteristic attribute parameter values, and then cluster the same types of parameters. Among them, principal component analysis is used to reduce dimensionality, and K-means clustering discretization is used [19]. The principal component analysis method has n samples, and each sample has k variables, forming a $n\times k$ order sample data matrix:

$$X=\begin{bmatrix}x_{11} & x_{12} & \cdots & x_{1k}\\ x_{21} & x_{22} & \cdots & x_{2k}\\ \vdots & \vdots & \vdots & \vdots\\ x_{n1} & x_{n2} & \cdots & x_{nk}\end{bmatrix}=[x_1,x_2,...,x_k] \tag{3}$$

Let the i-th column vector of X be $X_i,(i=1,2,...,k)$, and the linear combination of k vectors $X_1,X_2,...,X_k$ of the matrix is:

$$\left.\begin{cases}R_1=a_{11}X_1+a_{21}X_2+\cdots+a_{k1}X_k\\ R_2=a_{12}X_2+a_{22}X_2+\cdots+a_{k2}X_k\\ \cdots\\ R_k=a_{1k}X_1+a_{2k}X_2+\cdots+a_{ki}X_k\end{cases}\right\}\ i=1,2,\cdots,k \tag{4}$$

Let $a_i=(a_{1i},a_{2i},\cdots,a_{ki})^T$. The specific definition of the K-means clustering algorithm used in cluster analysis is as follows:

$$F=\sum_{i=1}^{k}\sum_{q\in D_i}\left|q-n_i\right|^2 \tag{5}$$

Among them, F,q are the sum of the mean square deviations of all objects in the database and a point in the object space; n_i is the mean value of cluster D_i.

(3) Usability analysis of product modeling

Usability is not a one-dimensional attribute and structure, but includes various interrelated elements. There are many explanations about the model architecture of usability. If the model is different, the attributes emphasized are also different, but they are all used to guide the design of a specific user interface. In the research on the human-computer interaction relationship of usability, the general concern is the ability of users to complete tasks normally during operation, so the time and efficiency of task completion and the error rate of task execution process are overemphasized. In many cases, a single degree of satisfaction cannot meet the requirements, and friendly products cannot provide usability correctly.

Usability evaluation indicators include learning, efficiency, memory, errors and satisfaction [20]. Learnability means that the system is easy to learn, and users can perform specific tasks in the operating system in a short time. Efficiency refers to the high efficiency of the system and the high level of productivity in use. Memorability means that the user can continue to use the system after not

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using the system for a certain period of time. Errors refer to the user's ability to reduce errors when using the system and avoid devastating errors. Satisfaction refers to the degree of user satisfaction when using the system, which is the subjective view of the user when using the system.

Usability evaluation methods include usability diagnosis method, usability test method and usability survey method [21]. The usability diagnosis method is simple, fast, and low-cost. There are also fewer evaluators required. The most common methods include heuristic evaluation and cognitive walkthrough. The usability testing method finds problems by observing how users use the interface of the system under test, and conducts a very comprehensive assessment of the usability of the interface. During the test, direct observation, interview, and questionnaire methods can be used to collect user behavioral response data.

2.3 Product Modeling Design

(1) General procedures for product design

Product modeling design is different from other designs. It is not only a three-dimensional material design, but also an abstract design of feeling; it not only integrates technology and products, but also integrates artistic aesthetics and products; products require both originality and market adaptability. Therefore, in product design, designers and teams must have in-depth and extensive professional knowledge in order to adapt to its complexity. The general procedure of product modeling design includes the following three stages.

In the first stage, the designer collects a large amount of available data, analyzes the situation of similar products or competing companies in the market, determines the positioning of the product design, and provides information support for the conceptual design of the second stage [22]. The main task of this stage is to collect and analyze data to obtain corresponding results. Therefore, whether the information is appropriate, complete, and novel will have a great impact on the results.

The second stage is the specific stage of the design work. Among them, the conceptual sketch design has few constraints on the designer, and there is a lot of room for innovation, which can best reflect the designer's experience, wisdom, and creativity, and play a decisive role in the quality of the design results. At this stage, there will be feedback on the first stage.

The third stage is mainly the product implementation, sales and feedback information collection stage. In order to improve and complete the product, the information obtained at this stage needs to be passed to the upper level.

(2) Product modeling design tasks

In the field of product modeling design, the input of design goals is expressed as the abstract intent of the product design project, including information components such as customer requirements, user requirements, and product recommendations [23]. The design project task book is a concrete manifestation of its form, which mainly includes the project background, project goals, project positioning, product concept elements, development team elements and some specific content.

In the process of product design, the behavior of product modeling design mainly includes various abstract activities such as action, language, thinking, recognition, appearance, etc. [24]. After the designer has a certain knowledge and understanding of the design problem, he executes independent detailed subtasks according to a certain relationship, performs a series of actions, and completes each subtask in turn. The realization of the final design goal is based on the reasonable planning and preparation of each subtask.

(3) Product modeling design knowledge

The acquisition of product styling design knowledge first requires sample screening, which can use multi-scale method and cluster analysis method [25]. Then the semantic feature Metadata is obtained, and the semantic difference method is often used. The product's semantic feature element information collection expression is shown in Formula 6:

$$P = \{word_1, word_2, \cdots, word_n\} \tag{6}$$

Among them, $word_n$ is the n-th intention word pair of the product.

Then the geometric features of the product modeling are obtained, and the entropy processing

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method is used to calculate the weight of each element in the geometric feature set. The participant's fuzzy decision matrix is shown in Formula 7:

$$CFS = [QC_{uk}]_{m\times n} \tag{7}$$

This matrix reflects the evaluation of each characteristic line by different subjects, and transpose the matrix to obtain Formula 8:

$$CFS = \left[QC'_{uk}{}^{t}\right]^{T}_{m\times n} = \left[QC'_{ku}{}^{t}\right]_{n\times m} \tag{8}$$

Each row in the matrix represents the vector used by the subjects to evaluate the same feature line, and entropy processing is performed on it, then the state probability of each subject acting on each feature line is shown in Formula 9:

$$Q_{uk} = \frac{QC_{uk}}{\sum_{k=1}^{m} QC_{uk}} \qquad k = 1,2,\cdots,m; u = 1,2,\cdots,n \tag{9}$$

According to the information entropy calculation formula, the evaluation information entropy of the u-th characteristic line can be calculated as shown in Formula 10:

$$E_u = \frac{1}{\ln(n)} \sum_{k=1}^{m} Q_{uk} \ln(Q_{uk}) \tag{10}$$

When $Q_{uk} = 0$, w=2 $Q_{uk} \ln(Q_{uk}) = 0$. The deviation degree is defined as:

$$d_u = E_u - 1 \tag{11}$$

Calculate the weight of each characteristic line according to the entropy weight calculation formula:

$$w_u = d_u / \sum_{u=1}^{n} d_u \tag{12}$$

Then the weight coefficient vector of the geometric characteristic line is shown in Formula 13:

$$W = [w_1, w_2, \cdots w_n]^T \tag{13}$$

Rough set can mine potential information from case products, describe and deal with problems objectively, so it can obtain modeling feature Metadata based on rough set. Assuming that QC_{xy} represents the average similarity score of the $x(x = 1,2,\cdots,s)$-th sample to the $y(y = 1,2,\cdots,q)$-th sample, the set of similar means of the x-th sample and other samples is shown in Formula 14:

$$R_x = \{QC_{xx+1}, QC_{xx+2}, \cdots, QC_{xg*h}\} \quad x = 1,2,\cdots,g*h \tag{14}$$

Suppose QC_{xy} is any certain element in R_x, the lower limit calculation and upper limit calculation of QC_{xy} are shown in Formula 15 and Formula 16:

$$L(QC_{xg}) = \frac{1}{QL_{xg}} \sum_{j} QC_{xg} \tag{15}$$

$$U(QC_{xg}) = \frac{1}{QU_{xg}} \sum_{j} QC_{xg} \tag{16}$$

Among them, j is all corner codes of $QC_{xj} \geq QC_{xg}$. Then the rough number is shown in Formula 17:

$$R(QC_{xg}) = [L(QC_{xg}), U(QC_{xg})] \tag{17}$$

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3. Experiments on Virtual Reality Technology Assists Product Modeling Design

3.1 Virtual Design of Product Modeling

(1) Application of virtual reality technology in product modeling design

The basic process of product modeling design includes analyzing product requirements, proposing conceptual products, defining product prototypes, developing new products, and prototype testing. As shown in Figure 1, in these links, virtual reality technology can be applied to product demand analysis and prototype testing. This research takes a new refrigerator product planned to be developed by a household appliance company as an example.

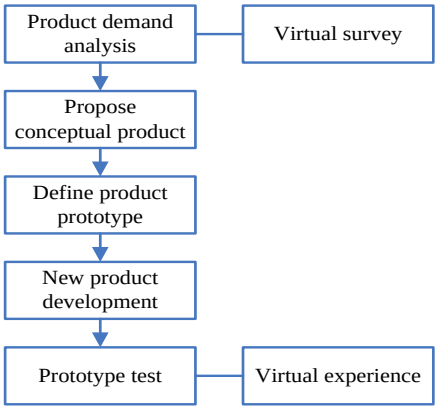

Figure 1: Flow chart of product modeling virtual design

Market research is needed in the product demand analysis link. This research is based on virtual reality technology and supported by existing market research theories, and proposes a virtual research survey method. The survey includes users' opinions on refrigerators, purchase motivations, and usage experience, etc., to understand users' needs and grasp the direction of market development.

After the concept product is proposed and successfully developed according to the demand, virtual experience is added to the prototype test link, which brings users an immersive, interactive and imaginative virtual experience, and feels the product's style and use effect. After users give information feedback, modify and improve the design according to the feedback.

(2) The realization framework of product modeling virtual design

The virtual design system of this research adopts the browser and server (B/S) structure, because it has the advantages of wide distribution, simple development, convenient upgrade and strong flexibility. The client roaming on the browser side is realized through ActiveX control combined with related web publishing technology. This research uses HTML language. The server uses Apache and Tomcat technology, combined with dynamic ISP pages, to realize a dynamic virtual browsing system.

After the web client is developed, it is evaluated, mainly for consumers, designers, marketers, product critics and outsiders. Carry out evaluations from different angles, obtain more accurate and reliable information, and further improve and perfect new products.

3.2 Database Construction of Product Modeling Virtual Design

(1) Scene modeling and effect optimization

In the simulation design of the virtual concept refrigerator, the common format .3ds format is used to complete the format conversion between software. Import the .3ds format model into Creator and use the combine faces command to synthesize the surface, which can improve the surface patch problem of the model in the virtual environment to a certain extent.

Delete some invisible faces in the model and control the size of the texture map to improve the loading speed of the model. Use LOD modeling technology to improve computer memory usage. Create a LOD node, place the model to be displayed under the node, and set the viewpoint distance through the node properties.

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(2) Texture mapping and optimized design

Use PS software to adjust the texture and tone of the picture accordingly, and then perform texture mapping after improving the visual effect. Refrigerators are home appliances, so the environment of their virtual experience is mainly a warm home environment, guiding the experiencer to better immerse themselves in the virtual environment.

The coordinates of the texture image are $(0,0)$ and $(1,1)$, the coordinate axis is represented by a,b, and the screen coordinate axis is represented by t,s. After the texture coordinates are mapped to the screen coordinates, the coordinates will change. In addition, in order to achieve the desired effect, the storage format of the texture image needs to be determined according to the situation.

(3) Realization of interactive effects

Use DOF technology to make the product model of the refrigerator move flexibly, realize the opening and closing action of the refrigerator door, and the action of pushing and pulling the drawer. Create DOF nodes, each node controls an action. Set the dm and dt nodes to control the refrigerator door and refrigerator drawer respectively, and set the door model and the drawer model under the dm and dt nodes respectively. After setting the local coordinate system, the range of freedom of movement is limited. The movement angle of the refrigerator door is 90 degrees, and the drawer moves in translation.

The setting of the dynamic display panel of the refrigerator also has a great influence on the effect of the virtual experience. This article uses dynamic text to achieve this effect. Create a Text file node, set its properties, and enter the path and name of the font file in the Font Name text box. For example, to set the freezer temperature, you need to set the adjustable maximum temperature and minimum temperature in the Value tab. In this way, the experiencer can experience the use of the new refrigerator in a virtual environment.

4. Discussion on the Effect of Virtual Reality Technology Assisted Product Modeling Design

4.1 Virtual Research Needs

(1) General situation of virtual survey users

3,000 virtual market survey questionnaires were cast through the home appliance shopping network platform to analyze users' views, purchase motivations, and usage experience of refrigerators, home appliances, to understand users' needs. A total of 1258 valid questionnaires were collected, and the general information of these 1258 users was analyzed, including age, gender, and educational background. The results are as follows:

Table 1: General information of users

Age		<25	25-35	35-45	45-55	>55	Total
Gender	Male	34	296	217	45	4	596
	Female	26	305	271	52	8	662
Total		60	601	488	97	12	1258
Education	Below high school	8	89	85	5	1	188
	High school	21	211	214	49	3	498
	College and undergraduate	23	264	155	31	5	478
	Master and above	8	37	34	12	3	94
Total		60	601	488	97	12	1258

As shown in Table 1, the 1,258 users participating in the virtual survey have a male-female ratio of 0.9:1, and there are 66 more females than males. The number of people aged 25 to 35 is the largest, accounting for 47.8%. The educational level is uneven, with the highest number of high school students accounting for 39.6%, and the number of masters and above is the least, accounting for only 7.5%. The differences in the ratio of men to women in different age groups are as follows:

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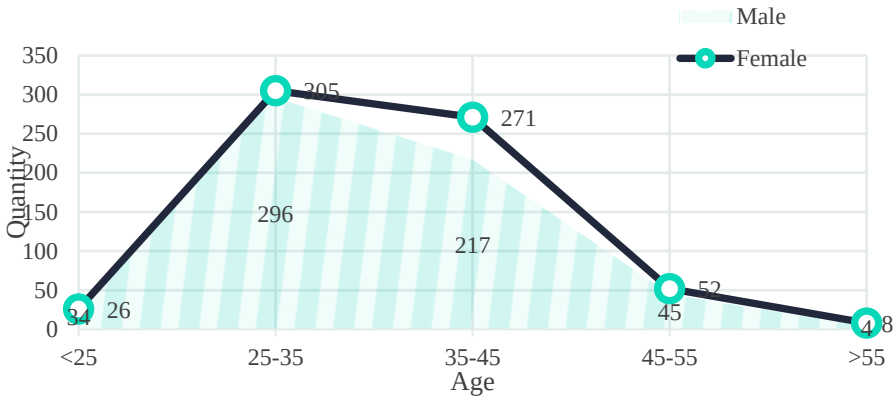

Figure 2: Comparison of the number of men and women in different age groups

As shown in Figure 2, among the 1258 users, there are 596 and 662 men and women. Among users younger than 25, the male to female ratio is 1:0.77; among users aged 25 to 35, the male to female ratio is 1:1.03; among users aged 35 to 45, the male to female ratio is 1:1.25; from 45 to 55 years old. Among users aged 55 years, the male to female ratio is 1:1.15; among users over 55, the male to female ratio is 1:2. The distribution of educational level of different age groups is as follows:

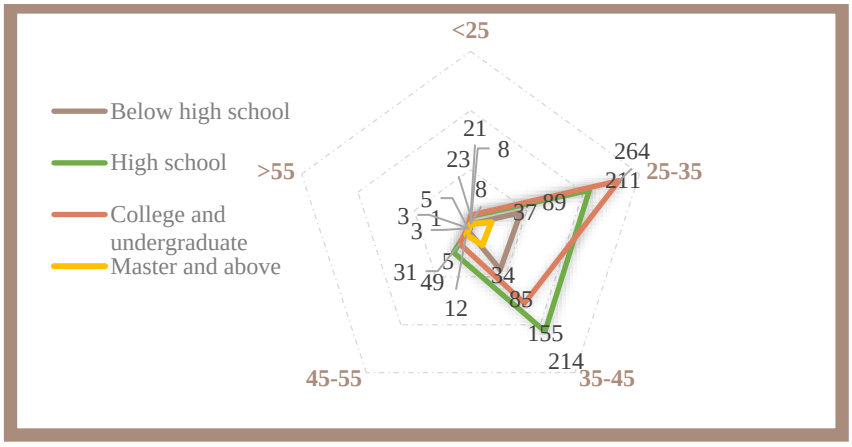

Figure 3: Distribution of education level of different age groups

As shown in Figure 3, among users younger than 25 years old, 25 to 35 years old, and older than 55 years old, the number of people with a college degree and a bachelor degree is the largest, 23, 264, and 5, respectively. Among users aged 35 to 45 and 45 to 55, the number of high school level users is the largest, 214 and 49 respectively.

(2) Virtual survey user demand analysis results

The survey content includes the factors that influence users' purchase behavior of refrigerators, which are home appliances. The following analyzes the primary factors affecting users' purchase of refrigerators from the perspective of different age groups. The factors involved include price, function, shape, energy saving, and capacity.

Table 2: Primary factors considered by users of different age groups when buying refrigerators

Factor	<25	25-35	35-45	45-55	>55	Total
Price	34	244	249	55	2	584
Function	5	148	121	20	5	299
Modeling	9	59	3	2	0	73
Energy saving	4	60	23	18	4	109
Capacity	8	89	92	2	1	192

As shown in Table 2, in addition to the user population over 55 years old, most of the other age groups said that the primary factor considered when buying a refrigerator is the price. Among the 584 users whose price is the primary factor, the number of users aged 35 to 45 is the largest, 249. Regardless of age, the primary factors considered by 1258 users when buying refrigerators are as

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follows:

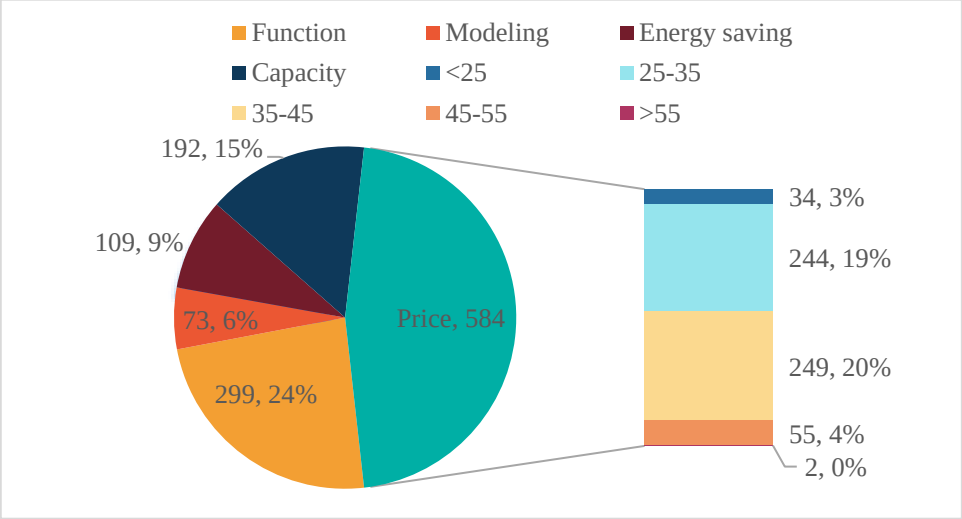

Figure 4: Distribution of consideration factors when buying refrigerators

As shown in Figure 4, in addition to the important factor of price, the order of the remaining factors is the function, capacity, energy saving and shape of the refrigerator, accounting for 24%, 15%, 9% and 6% respectively. Therefore, when proposing the concept product of refrigerator, appropriate functions and capacity should be set according to market demand. Of course, the most important thing is to set an appropriate price for the consumer market. Therefore, in the survey, we analyzed the price range that users with different educational backgrounds can accept when buying refrigerators.

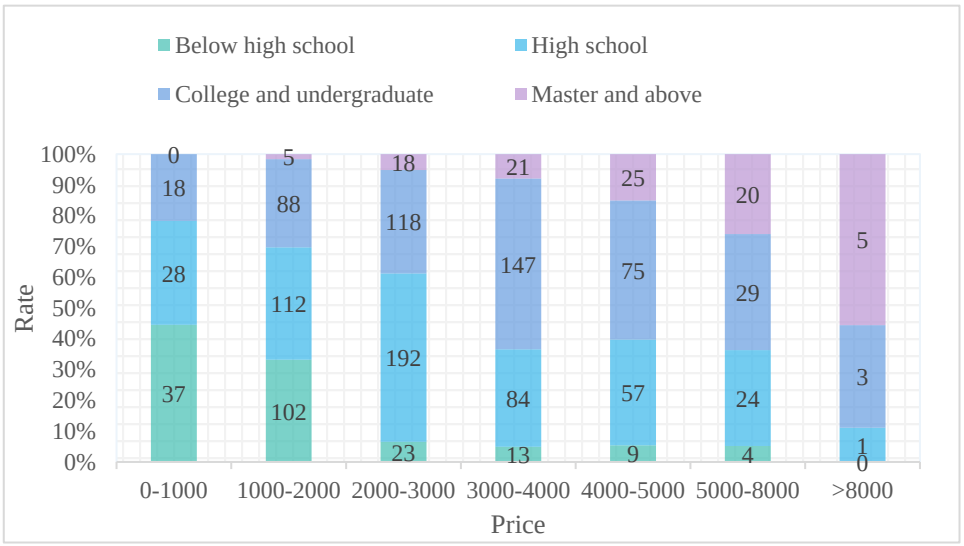

Figure 5: Price range of refrigerators that users with different educational backgrounds can choose

As shown in Figure 5, in general, the higher the educational level, the higher the price range selected by the user. There are 83 users who choose less than 1,000 yuan, and 44.6% of them have lower education level than high school. There are 307 users who choose between 1,000 and 2,000 yuan, of which 36.5% have a high school degree; and there are 351 users who choose between 2,000 and 3,000 yuan, and the highest proportion is a high school degree, which is 54.7%. There are 265 people who choose 3,000 to 4,000 yuan, and the highest proportion is college and undergraduate degrees, which is 55.5%; there are 77 and 9 users who choose 5,000 to 8,000 and more than 8,000 respectively. Therefore, when pricing the new product series of refrigerators, the price should be controlled at around 3,000 yuan, and then the price should be increased or lowered according to the capacity to meet the needs of different user groups.

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4.2 User Feedback and Evaluation of Virtual Research and Virtual Experience

(1) Evaluation results of virtual survey client page

Consumers, designers, marketers, critics, and outsiders are invited to evaluate the stability, ease of operation, and comfort of the web client. A scoring system is implemented, and the full score for each performance is 10 points. A score greater than or equal to 9 is rated as excellent, a score less than 9 and greater than 7 is rated as good, a score less than 7 and greater than 5 is rated as medium, and a score less than 5 is rated as poor. There are 3 evaluators for each identity, and the average score represents the overall score of each evaluator. The scores are as follows:

Table 3: Test scores on the client page

Evaluator	Stability score	Simplicity score	Comfort score
Consumer 1	9.3	8.2	8
Consumer 2	9.6	9	9.1
Consumer 3	9.6	8.9	8.4
Average score	9.5	8.7	8.5
Designer 1	8.9	9	8.5
Designer 2	8.4	9.5	9.5
Designer 3	9.1	10	9
Average score	8.8	9.5	9
Marketer 1	9.5	9.6	9.4
Marketer 2	10	9.3	9.2
Marketer 3	9.3	9.3	9.3
Average score	9.6	9.4	9.3
Critic 1	8.9	8.7	8.7
Critic 2	9.2	9.2	8.7
Critic 3	9.2	8.9	8.1
Average score	9.1	8.9	8.5
Outsider 1	9.8	8.7	9.1
Outsider 1	9.5	8.3	8.8
Outsider 1	9.5	8.5	9.1
Average score	9.6	8.5	9

As shown in Table 3, testers with different identities have different emphases, so the scores are not consistent. Consumers have higher requirements for the ease of operation and experience comfort of the client, so they are more picky. The designer's professional level is relatively high, so it is easy to detect whether the stability of the page is good. The distribution of scores is as follows:

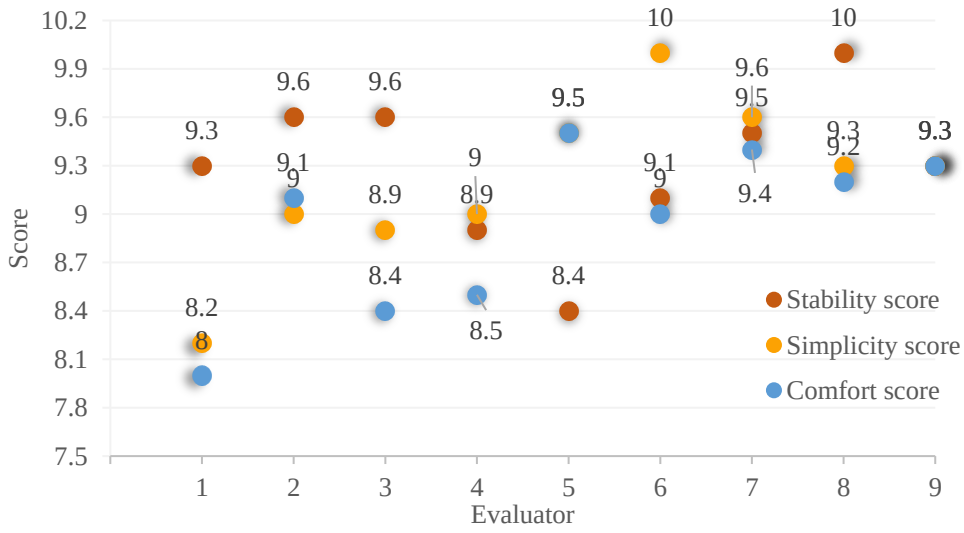

Figure 6: Score distribution

As shown in Figure 6, the scores are mainly concentrated between 9-9.5 points. The minimum score is 8 points and the maximum is 10 points. Indicates that the performance of the client page is excellent.

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The average scores of different status assessors for different performances are as follows:

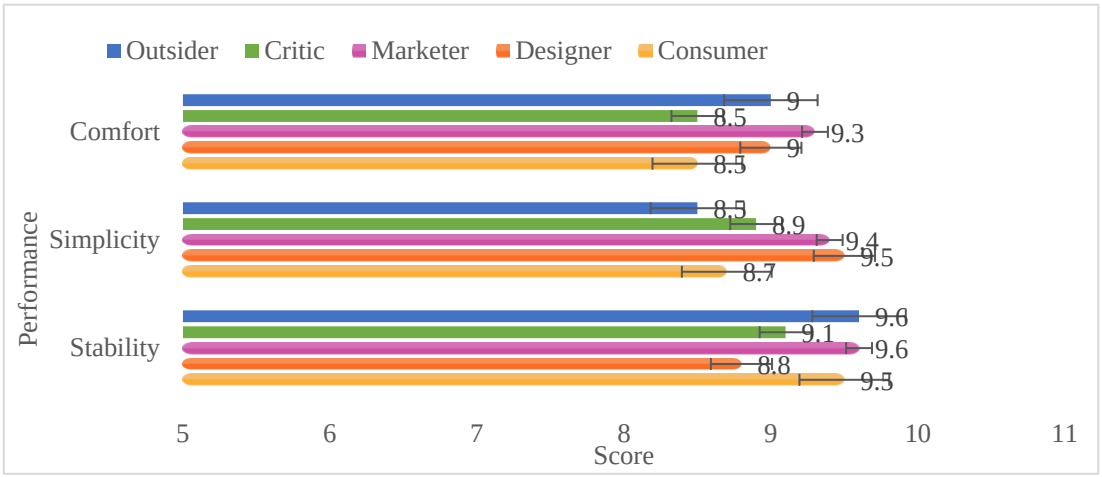
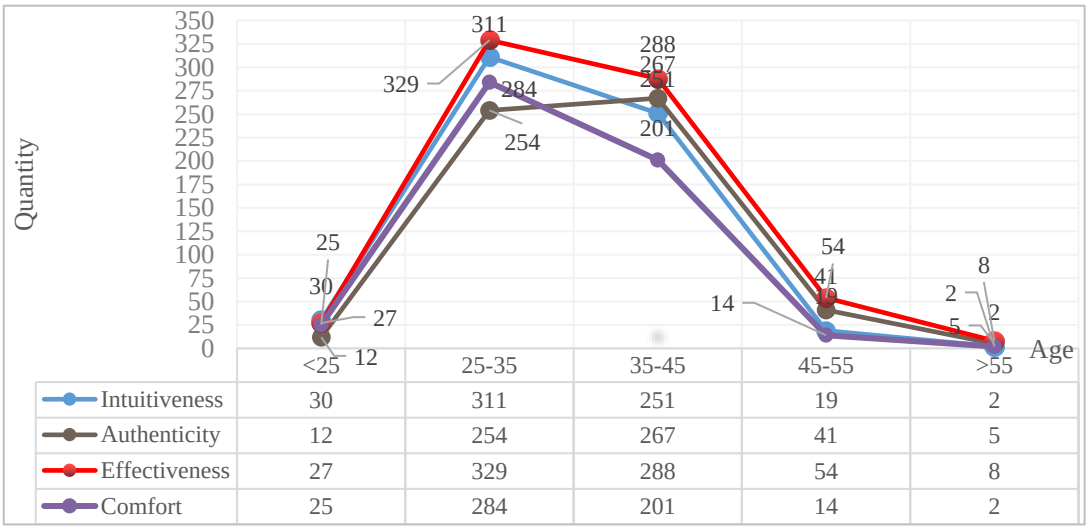


Figure 7: Average score of different performance

As shown in Figure 7, the highest comfort score is 9.3 points for marketers, the highest simplicity score is 9.5 points for designers, and the highest stability score is 9.6 points for outsiders and marketers. After calculation, the stability of the client page averaged 9.32 points, the ease of operation averaged 9 points, and the average experience comfort scored 8.86 points. This indicates that the experience comfort of the client page needs to be further improved.

(2) Feedback on the way of virtual experience

After the development of the new product, the client page is also optimized according to the evaluation results, and an invitation for the virtual experience is initiated to the users who have previously accepted the virtual survey. Among the 1258 users who accepted the virtual survey, 739 users participated in the virtual experience. After the virtual experience is over, give feedback on the effect of the virtual experience. Analyze the intuitiveness, authenticity, effectiveness, and comfort of virtual experience based on different age groups.



	<25	25-35	35-45	45-55	>55
Intuitiveness	30	311	251	19	2
Authenticity	12	254	267	41	5
Effectiveness	27	329	288	54	8
Comfort	25	284	201	14	2

Figure 8: User feedback on virtual experience

As shown in Figure 8, among the 739 users who participated in the virtual experience, 613 believed that the virtual experience was highly intuitive; 579 believed that the virtual experience was highly authentic. 706 people think the virtual experience is very effective and can better simulate real shopping; but only 526 people think the experience is more comfortable. Therefore, in terms of virtual experience, it is necessary to improve the comfort in the experience process and appropriately enhance the authenticity.

(3) Evaluation of the new product refrigerator

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According to the results of previous market research, there are three refrigerators in the new product series (A, B, C), and the capacity and price increase in sequence. The larger the capacity, the higher the price. In the virtual experience, three refrigerators are placed side by side to achieve a contrast effect. After the user experience is over, investigate their satisfaction with the new refrigerator. There are four levels of satisfaction (1, 2, 3, 4) for capacity, price, appearance color, and internal structure. The higher the level, the higher the satisfaction level.

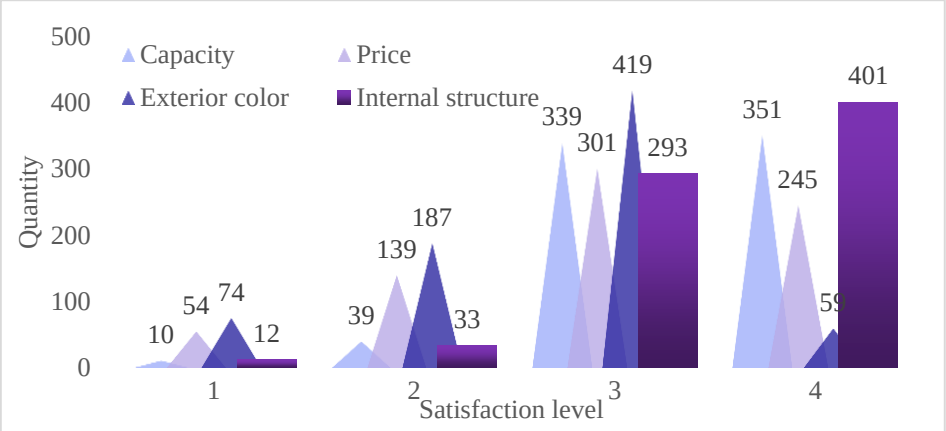

Figure 9: User satisfaction with refrigerators

As shown in Figure 9, 351 people said they were very satisfied with the capacity setting of the refrigerator, 245 people were very satisfied with the price of the refrigerator, 59 people were very satisfied with the appearance of the refrigerator, and 401 people said they were very satisfied with its internal structure. Therefore, after getting user feedback, the appearance of the new refrigerator should be adjusted in time to meet market demand.

At the same time, the user's purchase intention is counted, and the purchase intention of 3 refrigerators of different age groups is analyzed to determine the production quantity of the three styles.

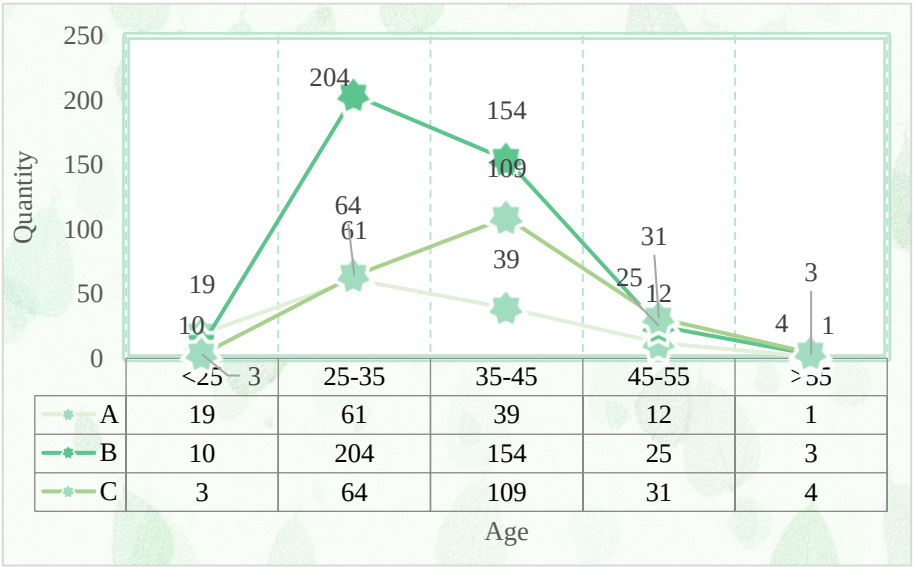

Figure 10: Purchase intentions of users of different age groups for 3 refrigerators

As shown in Figure 10, users under the age of 25 prefer the A model, users between the ages of 25 and 45 prefer the B model, and those over 45 prefer the C model. Overall, the purchase intention ratio of the three refrigerators A, B, and C is 1:3:1.6. Therefore, when arranging production, type B should be the main focus.

4.3 Advantages of Virtual Design

After the entire virtual design process is completed and put into production, by comparing the

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difference between virtual design and traditional design in cost and time, cost and time include three stages, namely research, development, and testing. Here the cost unit is ten thousand yuan, and the time unit is day.

Table 4: Comparison of cost and time between virtual design and traditional design

Comparison index	Virtual design	Traditional design	Difference
Research cost	7.14	18.38	11.24
Development costs	107.45	98.77	-8.68
Test cost	13.57	26.49	12.92
Total cost	128.16	143.64	15.48
Research time	7	21	14
Development time	85	80	-5
Test time	7	21	14
Total time	99	122	23

As shown in Table 4, in the research and testing phases, the cost of virtual design is much lower than traditional design, and the time is shorter. But in the development stage, the cost of virtual design is slightly higher than that of traditional design, and it takes a little longer. Because the development stage needs to consider the cost and time of the client and virtual environment modeling for the virtual experience. But in general, the total cost of virtual design is 154,800 yuan less than traditional design, and the total time is 23 days less. This fully reflects the superiority of virtual design. Comparison of cost and time at different stages:

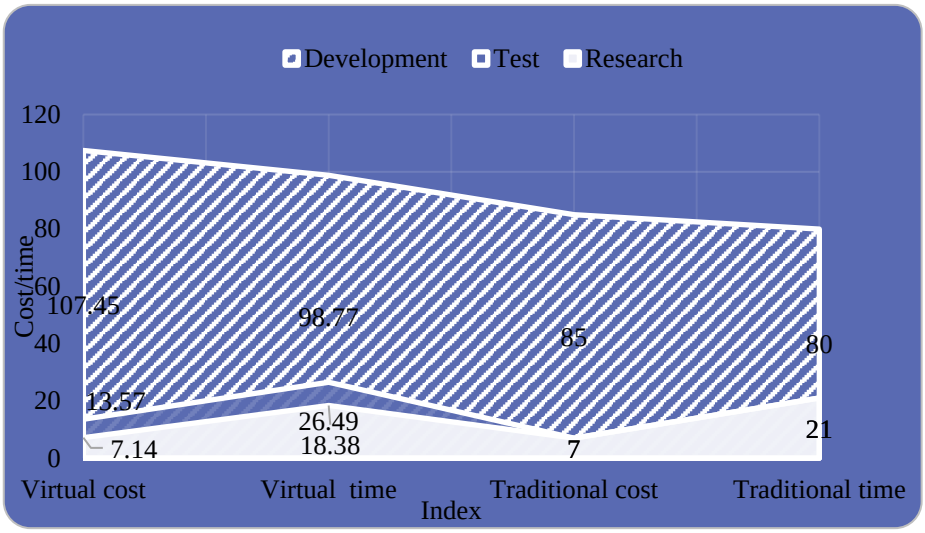

Figure 11: Comparison of cost and time at different stages

As shown in Figure 11, during the research phase, the cost difference between virtual design and traditional design was 112,400 yuan, and the time difference was 14 days. In the development stage, the cost difference between the two is 86,800 yuan, and the time difference is 5 days. In the test phase, the cost difference between the two is 129,200 yuan, and the time difference is 14 days.

5. Conclusions

This article integrates virtual reality technology into the two links of market research and prototype testing of conventional new product launches. After optimizing the comfort level, a virtual survey was randomly launched on the home appliance shopping website. Price is the first factor most users consider when buying a refrigerator, followed by function, capacity, energy saving and styling.

After obtaining sufficient demand and market information, develop new products, build a virtual design database, perform scene modeling, texture mapping, and achieve interactive effects. After the virtual experience is over, the comfort during the experience is improved based on feedback, and the appearance of the new refrigerator is adjusted in time to meet market demand. And according to the purchase intention proportion to arrange the production quantity. And after comparison, it is found that product modeling design based on virtual reality technology can save costs and improve efficiency, and it is worth promoting in the design field.

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However, due to the difficulty and intelligence of virtual reality technology, when the website initiates a virtual experience, the users participating in the research already have certain characteristics, which are relatively concentrated in terms of age and education. This will reduce the representativeness of the research data, so in the next research work, the research sample needs to be further expanded.

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