Research on Human-Machine Interface Design of Smart Refrigerator Based on Conjoint Analysis

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Abstract. The purpose is to study the design method of the smart refrigerator man-machine interface. The method adopts conjoint analysis, starting from the human-machine interface of the smart refrigerator, and splitting and orthogonally reorganizing the main components and element types of the interface, allowing users to score the virtual experiment scheme and statistical data, and calculate the utility value of each element and type, analyzes the user preference in the smart refrigerator man-machine interface, and then draws the design principles of the smart refrigerator man-machine interface, and generates the final interface design plan. This paper concluded that through the conjoint analysis method, multi-factor data could be statistically analyzed. Therefore, enable designers to better understand the user preference for the smart refrigerator man-machine interface, improve user experience and user viscosity, and providing ideas for similar interface design in the future.

1. Introduction

In the intelligent era of mobile internet, household appliances in daily life are becoming more and more intelligent with the development of technology. As one of the core home appliances in people’s lives, smart refrigerators are becoming more and more demanding for their actual and psychological needs [1]. In recent years, smart refrigerators with a new touch interface are gradually replacing the traditional refrigerator market, affecting users' operating habits. Smart refrigerators can effectively adjust the internal temperature through the control of the soft interface. At the same time, it can also scientifically and reasonably adjust the temperature of each compartment in the refrigerator according to storage requirements to improve the user's participation and satisfaction [2]. For enterprises which develop and produce smart refrigerators, it is very important to deeply study the information architecture, functional utility and visual perception of the human-machine interface. Furthermore, summarize the interface design that conforms to the user's behavioral logical habits [3]. Based on the conjoint analysis of the product elements and element types of the human-machine interface of the smart refrigerator, this paper evaluates the level and importance of each element from the user's perspective, explores the human-machine in line with the user's intentions and preferences. Thereby, deriving the interface design principles and optimization schemes for the better interface combination design to enhance the user experience.
2. An Introduction to Conjoint Analysis

Conjoint Analysis was a concept proposed by statistician Tukey and mathematical psychologist Luce in the 1940s [4]. This concept combines model design, information collection and measurement analysis and other methods to induce and analyze [5]. In conjoint analysis, each product is composed of different elements and different element levels. Users evaluate and score simulated products according to their own preferences. These scores can scientifically measure users’ psychological standards for each attribute of the product. By calculating its utility value and importance of these standards, researchers could determine the optimal product element combination model, and provide effective guidance for new product development [6].

In recent years, conjoint analysis has been widely used in many research fields. Take Chen Long and his team as an example, they used conjoint analysis to study the impact on consumer preferences of attributes including brand, warranty period, maintenance period, green label and purchase channel of official refurbished mobile phones [7]. In addition, Wu Wenting and her team conducted simulation scenario combination experiments on the collection, transmission, and storage of rainwater facilities in green fields based on conjoint analysis. They studied the facility design elements’ impact on user preferences, and propose suggestions for equipment improvement [8]. Zhang Guozheng and his team used conjoint analysis to study consumers’ preference for tea purchases, and analyzed consumers' purchasing decisions from attributes such as brand effect, geographical indications, and tea prices [9].

In conclusion, conjoint analysis method could evaluate the importance of elements of the product, and determine the optimal solution. The method of exploring the human-machine interface of refrigerator products could not only allow new users to adapt efficiently and quickly, but also consolidate the old users’ habits and enhance user viscosity.

The basic steps of conjoint analysis include: determining the attribute type and attribute level of a product or service, orthogonal experimental design, questionnaire design, data collection and analysis, calculating attribute utility and relative importance, result analysis, interpretation and application.

3. Conjoint analysis of human-machine interface of smart refrigerator

3.1. Component and type analysis

Through market research and analysis of the human-machine interface of smart refrigerators of various brands, analysis of competing products between brands, and consulting smart home appliance design experts, it is finally determined that the human-machine interface of smart refrigerators is roughly composed of six elements. (1) Interface layout, mainly refers to the location distribution, arrangement and style of graphic information, which together determine the overall effect of the interface [10]. The interface layout of this study mainly grouped and summarized the interface content in the smart refrigerator screen. Generally, the interface content was divided into refrigerator temperature adjustment, compartment selection, and quick cooling settings according to the functional mode of the refrigerator; (2) Text type, text is an important source for users to obtain visual information when using the refrigerator interface, so the expression of text plays an important role in the interface; (3) Icon style, refers to the manifestation of icons in the interface, including three types: pure line style, line and color combination style, and pure face style; (4) Thematic color matching, refers to the overall color perception of the interface. Different color systems will give users different impressions; (5) Animation effect settings, in the smart refrigerator man-machine interface Dynamic special effects can guide and prompt users to operate efficiently, not only make the interface vivid, but also relieve the user’s irritability while waiting for the system to respond, and improve the sense of experience; (6) Feedback prompt, refers to the system’s response to the user The interactive response of the operation can prompt the user of its valid or invalid operation.

According to the analysis, the different types of the six smart refrigerator human-machine interface elements are sorted and numbered, as shown in Table 1.
Table 1. Elements and types of refrigerator man-machine interface.

| Elements          | Types            | Type numbers |
|-------------------|------------------|--------------|
| Interface layout  | Listed           | 1            |
|                   | Tabbed           | 2            |
|                   | Desktop          | 3            |
| Text type         | Sans serif font  | 1            |
|                   | Serif font       | 2            |
|                   | Pure line        | 1            |
| Icon style        | Line & surface combination | 2 |
|                   | Pure surface     | 3            |
| Theme color       | Monochrome       | 1            |
|                   | Adjacent color   | 2            |
| Animation settings| Dynamic          | 1            |
|                   | No dynamic       | 2            |
| Feedback prompt   | Image            | 1            |
|                   | Sound            | 2            |
|                   | Shock            | 3            |

3.2. Orthogonal experimental sample design

According to the element types and numbers in Table 1, six key elements and 16 element levels that affect the human-machine interface of smart refrigerators are determined. According to the full-contour experiment method, $3 \times 2 \times 3 \times 3 \times 2 \times 3 = 324$ possible interface element combination samples can be obtained. This evaluation exceeds the later data collection ability and lacks representative significance. In order to ensure the accuracy and normal operation of the experiment, this paper uses the orthogonal test module of the SPSS software to orthogonally design the constituent elements, and simulates 16 representative and relatively small typical interface combination design schemes. See Table 2 for details, and some experimental samples are shown in Figure 1.

Table 2. 16 typical interface element combination design solutions.

| Number | Interface layout | Text type     | Icon style        | Theme color | Animation settings | Feedback prompt |
|--------|------------------|---------------|-------------------|-------------|--------------------|-----------------|
| 1      | Listed           | Serif font    | Pure line         | Monochrome  | Dynamic            | Shock           |
| 2      | Tabbed           | Sans serif font| Pure surface      | Monochrome  | Dynamic            | Sound           |
| 3      | Desktop          | Sans serif font| Pure line         | Colourful   | No dynamic         | Sound           |
| 4      | Listed           | Sans serif font| Pure surface      | Adjacent color | No dynamic     | Image           |
| 5      | Listed           | Serif font    | Line & surface combination | Adjacent color | Dynamic     | Sound           |
| 6      | Desktop          | Serif font    | Pure surface      | Monochrome  | Dynamic            | Image           |
| 7      | Listed           | Sans serif font| Line & surface combination | Colourful       | Dynamic     | Image           |
| 8      | Listed           | Serif font    | Pure surface      | Colourful   | No dynamic         | Shock           |
| 9      | Listed           | Sans serif font| Pure line         | Monochrome  | No dynamic         | Image           |
| 10     | Desktop          | Serif font    | Line & surface combination | Monochrome       | No dynamic | Image           |
| 11     | Tabbed           | Serif font    | Pure line         | Colourful   | Dynamic            | Image           |
| 12     | Tabbed           | Serif font    | Pure line         | Adjacent color | No dynamic | Image           |
| 13     | Tabbed           | Sans serif font| Line & surface combination | Monochrome       | No dynamic | Shock           |
| 14     | Listed           | Sans serif font| Pure line         | Monochrome  | Dynamic            | Image           |
| 15     | Listed           | Serif font    | Pure line         | Monochrome  | No dynamic         | Sound           |
| 16     | Desktop          | Sans serif font| Pure line         | Adjacent color | Dynamic | Shock           |
3.3. Experimental data collection and analysis

For the 16 samples designed, random sampling method was used to select 50 users who had experience in using the human-machine interface of smart refrigerators or had purchase intentions as the research target population, and rated the preference of the optimized typical combination scheme. To ensure the breadth of the survey, the sample population covers people aged 20-60, and covers different occupations and genders. The rating setting adopts the five-level Likert scale, and the rating range is set as follows: 1 represents "very dislike", 2 represents "do not like", 3 represents "does not matter", 4 represents "like it", and 5 represents "very much" like". At the same time, the Cronbach Alpha coefficient is used to statistically analyze the reliability of the questionnaire [11], and the Cronbach α coefficient is calculated by SPSS software to be equal to 0.657, indicating that the measurement reliability of the questionnaire is up to the standard and acceptable.

The survey data was imported into the Conjoint analysis module in the SPSS software to calculate the individual utility value, overall utility value, importance value, correlation and other statistics. Among them, the overall utility value and importance value are used as statistics to analyze the intention of the subjects, which are particularly important for the reference value of the subsequent design. The positive or negative value of the utility value reflects the attitude of the crowd to like or dislike the interface element type. The size of the value reflects the degree of like or dislike. The importance value data reflects the degree of importance the crowd considers when selecting interface elements, that is, the higher the data value, the more important the element is in the overall interface design. The overall utility value and importance are shown in Table 3.

| Elements          | Types                    | Utility value | Importance |
|-------------------|--------------------------|---------------|------------|
| Interface layout  | Listed                   | 0.121         | 18.080     |
|                   | Tabbed                   | -0.084        |            |
|                   | Desktop                  | -0.036        |            |
| Text type         | Sans serif font          | -0.024        |            |
|                   | Serif font               | 0.024         | 10.727     |
|                   | Pure line                | -0.011        |            |
| Icon style        | Line & surface combination | -0.144       | 19.258     |
|                   | Pure surface             | 0.154         |            |
|                   | Monochrome               | 0.121         |            |
| Theme color       | Adjacent color           | 0.070         | 20.820     |
| Animation settings| Dynamic                  | -0.056        | 9.694      |
|                   | Colourful                | -0.191        |            |
| Feedback prompt   | No dynamic               | 0.056         |            |
|                   | Image                    | -0.184        |            |
|                   | Sound                    | 0.042         | 21.421     |
|                   | Shock                    | 0.143         |            |
According to the experimental results in Table 3, among the six elements contained in the human-machine interface of the smart refrigerator, the user most valued the feedback prompt, followed by the theme color, followed by the icon style and interface layout, and the text type and dynamic effect. The importance of the setting is relatively low, indicating that the interaction feedback of the interface and the unity of colors are the most concerned elements of users.

Through the above analysis of the data, the element level with the highest utility value is selected and the optimal design model of the human-machine interface of the smart refrigerator is obtained: list style + serif font + pure face style + single color + no dynamic + vibration. According to the user preference data model, four design principles are proposed.

3.4. Principles of Human-Machine Interface Design for Smart Refrigerators
(1) Clear visual presentation. The clear and reasonable interface layout can visually present the content information of the product, enabling users to find the parts they need in a short time. Users prefer a list-style interface layout, which is a breadth-priority logical architecture in the interface information architecture, that is, users can perform more content operations in a single interface, and the interface layout and user behavior during operation also maintain a high level. Logical consistency can improve user operation efficiency and behavioral experience to a certain extent.

(2) Easy-to-read graphic display. The description of the text and the display of the icon are the most direct and important source for users to obtain visual information. Fonts can be roughly classified into serif fonts and sans-serif fonts. Users prefer serif fonts. Serif fonts will be easier to recognize, easy for users to read, and have certain decorative and artistic effects [12]; In terms of icon styles, users tend to be pure-faced, with simple forms and strong expressiveness, removing redundant decorative effects, and having a high degree of recognition.

(3) Comfortable feeling of color. Different tones of the interface will bring different visual experiences to users. In terms of color settings, users are more biased towards monochromatic colors. Choosing simple and consistent visual colors can not only help users recognize and understand the product, produce a comfortable experience, but also deepen the user's memory of the product brand and convey brand value.

(4) Multi-sensory behavior feedback. Interface feedback refers to the user's perception of operational behavior feedback after issuing instructions. In this experiment, users prefer the vibration feedback method. Research shows. In the same time and space environment, if two or more sensory channels are used at the same time, it can be determined that they are from the same object or event. Therefore, the input conditions under multi-sensory channels are easier to be detected than single sensory [13]. It can be seen that the feedback form should adopt multi-sensory channel input information, that is, combining the vibration feedback of the user's tendency, and integrating the visual and auditory feedback, which will enhance the interaction between the product and the user and enhance the user experience of the interface.

4. Design application case
4.1. Design of Human-Machine Interface of Smart Refrigerator
Based on this article's research on the design of the human-machine interface of smart refrigerators, the design principles are applied to the market's leading smart refrigerator Ronshen BCD-529 series for design improvement practices, and user satisfaction is analyzed to improve user experience. The machine interface design is shown in Figure 2.
In terms of clear visual presentation principles, the interface adopts a list interface layout as the main interface to present all functional content. At the same time, the user’s top-down human visual perception is used as a design reference to improve user operation efficiency.

In terms of easy-to-read graphics and text display principles, the icons on the interface adopt pure face expressions to make the information presented by the icons more concise and easier to recognize. The fonts adopt serif fonts that are easy for users to read, which reduces users' learning and cognitive costs.

In terms of the principle of color comfort, the color of the interface adopts the cool color system that is most related to the core functions of the refrigerator, which enhances user comfort and trust in the product, and a single color selection allows users to better remember brand products.

In terms of the principle of multi-sensory behavior feedback, the interface adopts a behavior feedback method that combines visual, tactile and auditory senses, that is, visually, the user’s operating position is accurately located through the transparency of the icon, and the tactile experience is successful in interacting through vibration. The short sound is used to ensure immediate feedback of user operations.

4.2. Design and application results analysis
In order to verify the rationality of the application of this method, 50 users (tested users are smart refrigerator users, college students, housewives, designers, etc.) were invited to design cases and the market’s leading smart refrigerator Ronshen BCD- The 529 series is evaluated. The questionnaire survey evaluates the interface aesthetics, interface innovation, and overall satisfaction. The evaluation system uses a 5-point scoring method. The larger the score, the higher the satisfaction. According to the results, the smart refrigerator man-machine interface design based on the conjoint analysis method has improved user satisfaction, as shown in Table 4.

| Smart refrigerator man-machine interface | Interface aesthetics | Interface innovation | Overall satisfaction |
|----------------------------------------|----------------------|----------------------|---------------------|
| Original design interface              | 3.86                 | 3.7                  | 3.96                |
| Optimized interface                    | 4.02                 | 4.22                 | 4.16                |

5. Conclusion
The human-machine interface of the smart refrigerator is the medium for the user to interact with the refrigerator, and its design should fully follow the design principles of user experience. Based on the conjoint analysis method, this paper uses the decomposition interface components and combination
schemes to study the design ideas of the man-machine interface, so as to provide a certain reference value for the research of the man-machine interface of the smart refrigerator. Due to the adoption of more subjective evaluation test and statistical methods, and the limited number of subjects, this study has certain limitations and deficiencies. The follow-up will consider combining advanced technology and more scientific methods to in-depth study of the human-machine interface of smart refrigerators.

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