Research Design of Intelligent Toothbrush for Preschool Children Based on KANO Model

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Abstract. In order to effectively obtain the user demands of children’s intelligent toothbrush and improve the use experience of children’s products. This paper explores user demands from the perspective of both parents and children. According to the Kano model, the user demands of both parents and children are analyzed, the nature of different demands is clarified, and the importance of various demands is calculated, so that the design can be targeted from the demands. Through this demand analysis method, we summarized the most important demands of children’s intelligent toothbrush, starting from what we can achieve the most satisfactory effect. In this paper, Kano model is used to analyze the demands of parents and children. Taking children’s toothbrush as a design case, the feasibility and validity of Kano model for children’s intelligent toothbrush are verified, and the user demands can be grasped more accurately.

1. Introduction
With the development of society, people’s demand for products has risen from the basic material demand to the psychological demand. The product design is no longer simply to meet the existing demands but should tap the potential demands of users. In recent years, children’s health problems have become a topic of particular concern, and oral health is one of the important criteria for physical health, which is especially in the process of children’s growth.

At present, children’s toothbrushes on the market are mainly traditional toothbrushes and electric toothbrushes. With the development of information technology, children’s toothbrushes are also developing towards the direction of intelligence [1]. The users of children’s toothbrush studied in this paper are special. Although the direct users are children, due to the lack of children’s cognitive ability, some demands are determined by the parents’ willingness. However, the current research on user demands only starts from the direct users themselves, without considering the impact of others on user demands. Taking children’s intelligent toothbrush as an example, this paper adopts KANO model to comprehensively consider and analyze the demands of children and parents, and then the functions, appearance, interaction and other aspects of children’s intelligent toothbrush are designed to improve user experience.

2. Analysis of Children’s Intelligent Toothbrush Based on KANO Model
This paper combines parents and children to analyzes user demands, sorts out the demands, and classifies them according to the level. For children’s intelligent toothbrushes, parents and children have different concerns. Parents may pay more attention to efficiency and safety, while children pay more attention to appearance and experience. If only parts of the demands are analyzed, it will cause great errors to the results. Therefore, both children and parents should be investigated at the same
time, and their main concerns should also be deeply explored when the questionnaire is set. As the cognitive level of children aged 3-6 is not enough to complete the questionnaire independently, the survey on children mainly adopts the method of user interview and survey on parents in the form of questionnaires.

2.1. Proposed Research Methods
The Kano model was proposed by Dr. Kano of Japan. He divided the user demands into Must-be Quality, One-Dimensional Quality, Attractive Quality, Indifferent Quality and Reverse Quality [2], which were represented by the letters M, O, A, I, and R respectively.

Through data review, user interviews, market research and other methods to determine user demands, and then use KJ method analysis, remove unnecessary demands, integrate similar demands, and finally we sort out the main 16 demands in table 1. Based on the demand list, further in-depth research will be conducted to produce a demand decision questionnaire, a Kano survey questionnaire, and a Kano satisfaction questionnaire.

Table 1. Summary of demands.

| C1 Cartoon characters | C5 Safe and comfortable material | C9 Game interaction | C13 Inspire enthusiasm |
|-----------------------|---------------------------------|--------------------|-----------------------|
| C2 Bright colors      | C6 Wireless charging            | C10 Correct brushing guide | C14 Timing service    |
| C3 Meet children’s size | C7 Gear adjustment             | C11 Record of brushing | C15 Reminder service |
| C4 Advanced cleaning technology | C8 Comprehensive cleaning | C12 Health feedback | C16 Display terminal |

The purpose of the demand decision questionnaire is to initially classify requirements according to the decision. If more than 85% of a demand is decided by the parents, it is considered that the demand is decided by the parents separately and classified as X1; if more than 85% of the demand is decided by the children, it is considered that the demand is decided by the children separately and classified as X2; The rest of the results are indicated to be jointly determined by parents and children, classified as X12. Then calculate the proportion determined by parents ‘Mi’ and proportion determined by children ‘Ni’ in class X12. Class X1 and X2 are subject to their respective results in various calculations. Class X12 is calculated according to the proportion determined by parents Mi and the proportion determined by children Ni.

When setting up the Kano survey questionnaire, Kano analysis requires that each question be asked from both the positive and negative aspects (when the demand is realized/when the demand is not realized), and the answer should be set as ‘like, necessary, indifferent, tolerable and dislike’. When conducting interview and surveys on children, the interview is conducted according to the same standard, with class X2 and class X12 as the main contents. The results of the survey will be classified according to table 2, and the results of the same problem are determined according to the maximum frequency of M, O, A, I and R [3]. Combining the demands of parents and children, the Kano demand model for children’s intelligent toothbrushes is created as shown in figure 1.

2.2. Demand Weight Analysis
According to Kano demand analysis, the calculation equation of user satisfaction index ‘Ti’ is equation (1) [4], where SI = (A+O)/(A+O+M+I), DI=(O+M)/(A+O+M+I). Berger [5] has proposed an algorithm to divided the increased satisfaction coefficient by the elimination of dissatisfaction coefficient, which can obtain the relative satisfaction SI (Ratio of satisfaction increase when demand is realized) and relative dissatisfaction coefficient DI (Ratio of satisfaction reduction when demand is not realized) of users. SI and DI values are positively correlated with the impact of user satisfaction. The closer the value is to 0, the smaller the impact of this demand on user satisfaction will be; the closer the value is to 1, the greater the impact will be.
Figure 1. Children’s toothbrush KANO demand model. This figure shows the results of the classification of demands according to the questionnaire and table 2.

Table 2. KANO model matrix for user demands.

| User demand | When demand is not realized | When demand is realized |
|-------------|-----------------------------|-------------------------|
|             | Like | Necessary | Indifferent | Tolerable | Dislike |
|             | Q    | A         | A           | A         | O        |
| Like        | R    | I         | I           | I         | M        |
| Necessary   | R    | I         | I           | I         | M        |
| Indifferent | R    | I         | I           | I         | M        |
| Tolerable   | R    | R         | R           | R         | Qa       |

Q is for the result in question.

\[ T_i = \max(|S_i|, |D_i|) \]  \hspace{1cm} (1)

When calculating the demand weight, the research results of parents and children are calculated separately. And the results of the parents are represented by capital letters, and the results of the children are represented by lowercase letters in all the equations. For example, in equation (2), ‘\( T_i \)’ represents the satisfaction index of the parents, and ‘\( ti \)’ represents the satisfaction index of the children. The satisfaction index of the \( X1 \) and \( X2 \) is directly expressed by ‘\( T_i \)’ and ‘\( ti \)’, and the satisfaction indexes of \( X12 \) are expressed by equation (2).

\[ T_i’ = T_i \cdot M_i + t_i \cdot N_i \]  \hspace{1cm} (2)

Kano satisfaction questionnaire surveys user’s satisfaction of each demand. We ask users to rate each demand and determine an ideal score with 5-order Likert scale (5 is the most satisfied, 1 is the least satisfied). The average of the survey results is taken as the current satisfaction of the demand ‘\( S_i \)’ and the target satisfaction ‘\( S_0 \)’. For children aged 3-6 years, Likert scale method is too abstract to understand for them. Therefore, it is necessary for us to adopt a simple way to help children understand in the survey, so as to obtain children’s accurate demand satisfaction. Then the target improvement rate ‘\( V_i \)’ of each demand is expressed by equation (3) [6]. The target improvement rate of class \( X1 \) demands and class \( X2 \) demands is directly expressed by \( V_i \) and \( vi \), and the improvement rate of class \( X12 \) demand is expressed by equation (4).

\[ V_i = S_0 / S_i \]  \hspace{1cm} (3)
\[ V_i = V_i \cdot M_i + v_i \cdot N_i \]  \hspace{1cm} (4)

In the Kano model, the importance of the five types of user demands \((M, O, A, I, R)\) varies greatly, and the impact on user satisfaction is also different. In order to calculate the improvement rate of demand more accurately, the coefficient ‘\( k \)’ is introduced, and the value of ‘\( k \)’ is related to five types of user demands \((M, O, A, I, R)\), the value of indifferent quality \((I)\) is 0, the value of must-be quality \((M)\) is 0.5, the value of one-dimensional quality \((O)\) is 1, and the value of attractive quality \((A)\) is 1.5. The adjusted demand improvement rate ‘\( R_i \)’ is expressed by equation (5).

\[ R_i = \frac{1 + T_i}{k} \cdot V_i \]  \hspace{1cm} (5)

During the questionnaire survey, the weight of each demand is scored and donated by ‘\( H_i \)’. The score ranged from 1 to 5, with 1 being the least important and 5 being the most important. The average value is used as the final score of each user demand weight. On the basis of ‘\( R_i \)’, and in combination with the user demand weight ‘\( H_i \)’, the importance of each demand ‘\( W_i \)’ is obtained, which is expressed by equation (6).

\[ W_i = R_i \cdot H_i \]  \hspace{1cm} (6)

The above analysis comprehensively considers the user’s demand satisfaction, target improvement rate and demand importance, and comprehensively reflects the importance of all the user demands [7]. The data list of all the calculation results are shown in table 3.

| Demand number | Decision type | Kano type | SI | DI | Ti/\( ti \) | Hi/\( hi \) | Si/\( si \) | S0/\( s0 \) | \( V_i/\( vi \) \) | \( R_i \) | \( W_i \) |
|---------------|---------------|-----------|----|----|-----------|-----------|----------|----------|-------------|--------|--------|
| C1            | X1            | A         | 0.67 | 0.07 | 0.67 | 4.21 | 3.02 | 4.15 | 1.37 | 2.97 | 12.50 |
| C12           | X12           | A         | 0.73 | 0.15 | 0.73 | 3.93 | 2.75 | 3.76 | 1.37 | 3.06 | 12.04 |
| C5            | X2            | M         | 0.41 | 0.87 | 0.87 | 4.52 | 2.63 | 4.92 | 1.87 | 2.56 | 11.58 |
| C10           | X2            | O         | 0.67 | 0.52 | 0.67 | 3.45 | 2.33 | 4.20 | 1.80 | 3.01 | 10.39 |
| C8            | X2            | O         | 0.62 | 0.48 | 0.62 | 3.75 | 2.73 | 3.97 | 1.45 | 2.36 | 8.83  |
| C3            | X12           | M         | 0.27 | 0.90 | 0.90 | 4.60 | 3.64 | 4.67 | 1.28 | 1.77 | 8.14  |
| C13           | X12           | O         | 0.71 | 0.48 | 0.71 | 3.74 | 3.13 | 3.97 | 1.27 | 2.17 | 8.11  |
| C9            | X12           | A         | 0.52 | 0.10 | 0.52 | 3.04 | 2.63 | 3.74 | 1.42 | 2.66 | 8.08  |
| C14           | X12           | A         | 0.53 | 0.18 | 0.53 | 3.61 | 3.65 | 4.31 | 1.18 | 2.23 | 8.07  |
| C2            | X1            | A         | 0.61 | 0.90 | 0.61 | 3.75 | 3.93 | 4.13 | 1.05 | 2.14 | 8.04  |
| C4            | X2            | M         | 0.35 | 0.49 | 0.49 | 3.64 | 2.55 | 4.34 | 1.70 | 2.08 | 7.56  |
| C15           | X12           | A         | 0.55 | 0.17 | 0.55 | 2.95 | 2.93 | 3.77 | 1.29 | 2.48 | 7.33  |
| C7            | X12           | A         | 0.47 | 0.22 | 0.47 | 2.97 | 3.04 | 4.33 | 1.42 | 2.09 | 6.22  |
| C6            | X2            | I         | 0.39 | 0.21 | 0.39 | 2.69 | 2.71 | 3.91 | 1.44 | 1.44 | 3.88  |
| C11           | X2            | I         | 0.51 | 0.10 | 0.51 | 2.71 | 3.24 | 3.94 | 1.22 | 1.22 | 3.30  |
| C16           | X2            | I         | 0.35 | 0.26 | 0.35 | 2.92 | 3.46 | 3.85 | 1.11 | 1.11 | 3.25  |

3. Design Implementation

Before the design implementation, we have to determine a design theme that fits the children’s preferences and product features, and then develop the design of function, interaction, appearance and other aspects around this theme. The theme of "sea world" was finally determined, which is in line with children’s curiosity to explore the unknown and conforms to the functional features of the product.
3.1. Functional Design
According to the above analysis, we sorted out the following functions and sorted them in descending order of ‘Wi’: C12 Health feedback, C9 Game interaction, C14 Timing service, C8 Comprehensive cleaning, C4 Advanced cleaning technology and C15 Reminder service.

- In the health feedback function, users can have their teeth scanned regularly and feedback the tooth health status to the app like figure 2a.
- The function of the game interaction is to connect the toothbrush with the app through Bluetooth. When brushing your teeth, there is a corresponding game on the app that can interact with the brushing action, gamifying the brushing process, and adding the right method of brushing the teeth during the game actions. Make children unconsciously form good brushing habits during brushing figure 2d.
- The timing service can ensure that the brushing time is enough for two minutes. If the brushing time is not long enough, the food residue and soft dirt on the teeth cannot be removed in time [8].
- Children aged 3 to 6 years old have small oral volume, newly developed permanent teeth and gums are very fragile [9]. Therefore, sonic vibration cleaning is selected as the cleaning technology. Compared with mechanical friction cleaning, it is less harmful to the teeth and more thorough cleaning.
- The reminder service includes brushing time reminder and brush replacement reminder. Users can customize the reminding time on the app, and the color changing bristles is used to remind the replacement of the brush. When the bristles are completely faded, the brush needs to be replaced.

3.2. Interaction Design
The part of interactive design mainly involves the design of interactive software and interactive hardware. Interactive hardware includes detector, bluetooth module, battery and processing chip. The detector can determine the position of the toothbrush and transmit the information to the terminal through the bluetooth module. When designing interactive software, considering the cognitive ability and interactive ability of children at this age, we designed an interactive game with appropriate operation complexity and information content [10]. So we designed a game to eliminate bacteria. The game interface takes the undersea world as the background and maps children’s oral environment. Bacteria can show up on the coral and eat the coral, where and when the bacteria appear can guide children’s brushing. In the game, the toothbrush in children’s hands will be mapped as a weapon to eliminate bacteria, which can be used to gain experience and upgrade into a new scene. In the process
of eliminating bacteria, treasure boxes will randomly appear with gold coins, and users can buy weapons and skins in the store figure 2c.

3.3. Appearance Design
In terms of appearance, the descending order of the importance of demands are ‘C1 Cartoon characters’, ‘C3 Meet children’s size’ and ‘C2 Bright colors’. Among them, ‘C1 Meet children’s size’ belongs to Must-be Quality, ‘C1 Cartoon characters’ and ‘C2 Bright colors’ belong to Attractive Quality. The size setting of toothbrush should be based on the national standard. Since there is no unified national standard for electric toothbrushes, we take the size in the national standard for children’s toothbrushes as a reference. The product size figure 3 shall meet the requirements of table 4 [11]. Under the premise of meeting the national standards, the physiological and psychological scales of children should be considered comprehensively. Toothbrush should be combined with children’s physiological characteristics, designed as a circular arc, and the bristles should be controlled within three rows, and the brush surface should cover 2-3 teeth [9].

![Figure 3. Children’s intelligent toothbrush size diagram.](image)

Table 4. Children’s toothbrush size table.

| No. | Items                   | Require (mm) | Size (mm) |
|-----|-------------------------|--------------|-----------|
| 1   | Brush length (A)        | ≤29.0        | 15.0      |
| 2   | Brush width (B)         | ≤11.0        | 10.0      |
| 3   | Brush thickness (C)     | ≤6.0         | 5.0       |
| 4   | Brush height (D) Flat type | 7.0~11.0    | 10.0      |
|     | Special type            | 5.0~12.0     | —         |
| 5   | Bristle diameter θ      | ≤0.18        | —         |
| 6   | Total length (L)        | 110.0~180.0  | 150.0     |

The variety of toothbrush colors is more suitable for children’s preferences. In addition, under the background of today’s design, simplicity has become a way of green design. At the same time, in order to better help children deepen the intimacy of toothbrushes, auxiliary elements such as cartoon images on toothbrushes should be weakened [12]. In order to coordinate the contradiction between children’s love for cartoon images and the fact that cartoon images will distract children from brushing their teeth, the cartoon image on the toothbrush will only select the features of marine animals as cartoon elements. We chose the characteristic elements of shark, crocodile and turtle. Cartoon elements are mainly displayed on the decorative shell of toothbrush handle. The decorative shell of toothbrush adopts soft silicone material to feel comfortable and act as a buffer. The decorative shell can be easily separated from the main body of the toothbrush. Each set of toothbrush is equipped with a different decorative shells, and users can change the shell according to their preferences figure 4. According to the color features of the cartoon characters, we determined that the shark shell is blue, the crocodile shell is green, the turtle shell is pink, and the toothbrush body is white.
Figure 4. Toothbrush decorative shell renderings.

4. Conclusion
Through the design of children’s intelligent toothbrush, the feasibility and validity of Kano model in analyzing children’s intelligent products are verified, and this method is explored in accordance with the actual situation of the research object. Kano analysis method mainly quantifies the user demands, so that people can intuitively see the importance of the demands. In the research of children’s products, the direct and indirect users are comprehensively considered, which improves the accuracy of demand analysis and helps enterprises accurately grasp user demands and develop innovative products to meet the demands.

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