Research on Children’s Smart Water Cup Design Based on Analytic Hierarchy Process

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Abstract. The children’s product market continues to expand, as a smart product with more contact with children’s mouth and hands, the design of children’s smart water cup needs to meet higher requirements. This paper studies the product value attribute of children’s smart water cup, explores the design possibility, and transforms it into a product in line with the market trend. Through market research and patent search to find design trends and combined with user interviews, children’s smart water cup products are decomposed into indicators to be evaluated, and quantitative data, The weight of each indicator was calculated by using Analytic Hierarchy Process (AHP) and the comprehensive score was ranked, and the design concept of children’s smart water cup was proposed. The introduction of Analytic Hierarchy Process in the design of children’s smart water cup can effectively reduce the interference of scattered elements and improve the design efficiency.

1. Introduction
Since January 2016, China has implemented a universal two-child policy, the number of births has increased significantly, the size of the children’s product market has also expanded, and the standards for children’s products have increased accordingly. As the most common product contact with children’s mouth and hands, the design and improvement of children’s smart water cup are inevitable trends [1]. For children, 500 to 1000 milliliters of water are needed every day [2], excessive or insufficient drinking water are not good for health. Therefore, developing good drinking habits is extremely beneficial for children’s growth. The functional structure design of the existing children’s smart water cup is still in the exploration stage, and the form is relatively simple. Therefore, this paper uses the Analytic Hierarchy Process (AHP) to evaluate and rank the value attributes of children’s smart water cup, transforming product value opportunities, improving design efficiency, and providing reference for follow-up children’s smart water cup design.

2. Children’s Smart Water Cup Design and Analysis
2.1. Significance of Children’s Smart Water Cup Design
The children’s smart water cup is a combination of smart and ordinary children’s water cup, generally consisting of a cup lid, a cup body, a cup bottom and a smart control system. It has the functions to remind drinking water, water temperature control and display, disinfection, sterilization and so on. In addition, it accords with the aesthetic characteristics of children such as cute and cartoon appearance, gradually being chosen by more parents and children, children’s smart water cup market continues to
expand. With the increasing demand of consumers and fierce market competition, how to maintain competitiveness and update products quickly has become the core issue of design [3].

By incorporating the Analytic Hierarchy Process into the design of children’s smart water cup, evaluation index system is constructed, and the score of each index affecting its design are obtained, the factors to be evaluated are reduced, and the dependence on the designers experience is reduced so as to develop more competitive children’s smart water cup products.

2.2. Introduction to Analytic Hierarchy Process
Analytic Hierarchy Process (AHP) is a hierarchy weight decision analysis method proposed by Professor Saaty, an American operations research scientist, in the early 1970s [4-5]. By decomposing the target factors related to decision-making into levels of objectives, criteria and schemes, and combining qualitative and quantitative analysis, a multi-level analysis structure model is formed to compare the relevant factors between layers and test whether the results are reasonable [6-7]. The steps are as shown in figure 1.

![Analytic hierarchy process flow chart.](image)

3. Extraction of Children’s Smart Water Cup Product Evaluation Index

3.1. Market Environment Analysis
With the rapid development of intelligence, technology and daily life are increasingly integrated. To some extent, the appearance of the smart water cup [8] reflects that people’s views on drinking water has changed from self-consciousness to external reminding. Healthy drinking water has gradually gained attention, and people realize its importance and necessity.

By selecting several smart water cups sold in market for analysis, as shown in table 1, it can be seen that the basic function of the commercially available smart water cup is to remind people to drink water, and the reminder methods include vibration, flashing lights, prompt sound and so on. Some smart water cups will be combined with software programs to interact with people via interfaces such as mobile phones or bracelets. Real-time reminders are based on the actual information of the user through a specific water balance algorithm.

There are fewer brands of smart water cup designed for children, including one called Gululu [9], an interesting and attractive children’s smart water cup which interacts through electronic pets.
formation game. And it is a relatively mature and excellent representative children’s smart water cup brand.

Based on market research, it can be found that the existing smart water cups remind people to drink water through visual and auditory, such as flashing lights, vibrations and prompt sounds. The key is whether people are willing to drink water. In addition, the thicker thermos cup structure is also subject to seasonal restrictions as well as other problems. As far as children are concerned, the smart water cup increases their weight to a certain extent. There are many kinds of water cups specially prepared for children in a family, and it is hard to meet the demand with just a thermos-style smart water cup.

| Name            | Material      | Screen | Reminder | Electricity            |
|-----------------|---------------|--------|----------|------------------------|
| Moikit cuptime  | Tritan        | Have   | Vibration| Lithium battery        |
| Moikit seed     | Stainless steel| Have  | /        | Lithium manganese battery|
| Moikit gene     | Tritan        | Have   | APP      | Lithium battery        |
| SGUAI           | Aluminum alloy| Have   | Sound    | Polymer battery        |
| Aidebar         | Stainless steel| None  | Flash    | Button battery         |
| GOC IN C        | Stainless steel| Have  | APP      | /                      |
| Heydo           | Tritan        | Have   | Flash and sound | Lithium battery |
| Gululu          | PP plastic    | Have   | Interactive game | Wireless charging |

3.2. Technical Environment Analysis

By searching the keyword “children smart water cup” through the SooPat patent search platform, there are 34 patents as of April 2019, including 9 invention patents, 11 utility model patents and 12 design patents. Through the analysis of these 34 patents, we can find that the patent design of children’s smart water cup mainly focuses on the appearance, with the keywords of roundness, sphere, high color saturation, cartoon and so on. Functional innovations are reflected in the use of sensors to detect movements or the status of drinking water, recording and monitoring of drinking water, supplemented by sound or vibration to remind drinking water, in addition to smart components for temperature control, sterilization and GPS positioning, and by playing Music or telling stories to attract children’s attention and arouse their interest in drinking water.

Analysis of the relevant patent application time, the domestic children’s smart water cup patent was first applied in 2011, concentrated in 2015-2018, and there is an increasing trend which also explains to some extent that the combination of children’s water cup product design and intelligence is more and more closely, the children’s smart water cup market has a trend of expanding.

3.3. Product Evaluation in Indicators Extraction

Starting from four steps of the Analytic Hierarchy Process, combining with the analysis of market environment and technology environment to extract product opportunities gap and property value of children’s smart water cup, which are constituent elements layer of the analytic hierarchy process (the bottom) and the guidelines layer (middle layer).

3.3.1. Product Opportunity Gap Extraction. “Creating breakthrough products” co-authored by Professor Jonathan Cagan of Carnegie and Professor Craig M Vogel, former president of the American Association of Industrial Designers, refers to the concept of “product opportunity gaps”. It is pointed out that the product opportunity gap will appear when there is a gap between the existing product and the new trend driven by the new product or the significant product improvement possibility [10]. Through competitive product analysis and patent enquire, the following children’s smart water cup product opportunity gaps are extracted:

- Color matching: The children’s products on the market are mostly bright colors, such as yellow, red, green, blue and other bright and saturated colors. Nowadays, children are more assertive,
gradually emphasize personality, and have decision-making power in product purchase. Personalized color matching will attract children’s attention and generate desire to purchase [11];

- Appearance: Taking into account the safety principle [12], children’s products are mostly sleek and styling, avoiding sharp. In the children’s smart water cup design patent, more hemispherical cup lids are used, combined with cartoon shapes or flat patterns, but the breakthrough is not big;
- Material selection: The tactile texture and visual texture of the material have a certain impact on the product experience. The commercially available cups are mostly made of plastic or stainless steel. It is especially important to choose materials suitable for children’s hands and mouths contact;
- Clean and hygienic: Some smart water cups have a disinfection and sterilization module to ensure the water quality is clean to some extent. In addition, attention should be paid to the drinking process and daily cleaning, too;
- Easy to use: Compared to adult smart water cup, the children’s one is smaller, mug general appearance of the same, but the load has increased, increases the lithium manganese battery or other power storage portion and associated sensor processing along with insulation function. It is equivalent to adding a part of the weight to the vacuum cup. It is not as light as a normal plastic cup, which will add extra weight to children. The more complicated use also increases the operational burden;
- Strong and durable: There are a wide variety of children’s cups, and different cups will be replaced depending on the season, making it difficult to meet most of the demand with thermos-style glasses alone;
- Interesting interaction: The main function of the smart water cup is reflected in the reminder of drinking water, but there are certain drawbacks in the current reminder method. The commercially available children’s smart water cup can be divided into two interactive ways. One is to attract children’s attention through the flashing lights or vibrating sounds, mainly relying on children’s consciousness and cannot guarantee the effect. The other is like Gululu Smart Water Cup, relying on creating a complete interactive system, using the development game to attract children’s attention, which is equivalent to combining the water cup with the game, and that may lead to too much obsession with the game while making the drinking water interesting.

3.3.2. Product Value Attribute Extraction

- Aesthetics: From a visual point of view, including color, modeling, and so on, combined with children’s product characteristics and children’s physiological behavior characteristics;
- Security: Safety is an extremely important point in children’s products design, including health safety, safety of use and so on, and attention should be paid to the shape and structure, too;
- Usability: Use smooth, simple procedures, except for the basic task of drinking water, other operations should be reasonable, in line with the physiological and behavioral characteristics of children;
- Interesting: Inducing children’s drinking interest, and further training to develop healthy drinking habits, it needs to be guided by fun, and can be reflected in appearance, actual operation, interaction and other aspects [13].

4. Application of Analytic Hierarchy Process in Children’s Smart Water Cup Design

4.1. Construction of Tomographic Structure Model

After conducting market and technical research on children’s smart water cup and consulting relevant literature, the children’s smart water cup design evaluation A is divided into four aspects: aesthetic $B_1$, security $B_2$, usability $B_3$ and interesting $B_4$. The criterion layer constructs a first-level evaluation index set $B = \{B_1, B_2, B_3, B_4\}$. Through expert interviews and user surveys, it is concluded that the factor layer has the following seven aspects, namely color matching $C_1$, appearance $C_2$, material selection $C_3$, clean and hygienic $C_4$, easy to use $C_5$, strong and durable $C_6$, interesting interactive $C_7$, to build a secondary evaluation index set $B_1 = \{C_1, C_2, C_3\}$, $B_2 = \{C_4\}$, $B_3 = \{C_5, C_6, C_7\}$.
Finally, the hierarchical model of the children’s smart water cup is obtained, as shown in figure 2.

![Figure 2. Hierarchical model for children’s smart cup design.](image)

### 4.2. Calculation of Design Index Weight of Children’s Smart Water Cup

If the system has n components, where A is the total objective and a\textsubscript{ij} is the relative weight of element i compared with j, then A=(a\textsubscript{ij})\textsubscript{n×n} Judgment Matrix can be constructed, a\textsubscript{ij} is the value scale 1-9. The digital increment represents the increased importance of element i than element j.

The Analytic Hierarchy Process is used to calculate the weights of the children’s smart cup design indicators, and the judgment matrices A- B, B\textsubscript{i}-(C\textsubscript{1}-C\textsubscript{3}), B\textsubscript{3}-(C\textsubscript{5}-C\textsubscript{6}) are constructed. The data is processed by data normalization, and the dimension and dimension unit interference are removed. The Excel table is used to calculate the feature vector W [14-15], and the component W\textsubscript{i} of the vector W is the hierarchical single order. And find the maximum eigenvector \lambda max and the consistency index CI, find the consistency index RI, and calculate the consistency ratio CR= CI/RI of each judgment matrix. The calculation results are shown in tables 2-4, if CR <0.1, indicates that it passes the consistency check, otherwise it needs to be adjusted. The following levels of indicator weights are obtained by calculation.

**Table 2. Judgment matrix A-B and its consistency test.**

| A     | B \_1 | B \_2 | B \_3 | B \_4 | W   |
|-------|-------|-------|-------|-------|-----|
| B \_1 | 1     | 1/3   | 1     | 1     | 0.097 |
| B \_2 | 5     | 1     | 3     | 5     | 0.555 |
| B \_3 | 3     | 1/3   | 1     | 3     | 0.252 |
| B \_4 | 1     | 1/3   | 1     | 1     | 0.097 |

**Table 3. Judgment matrix B\_1-(C\_1-C\_3) and its consistency test.**

| C \_1 | C \_2 | C \_3 | W    |
|-------|-------|-------|------|
| 1     | 3     | 7     | 0.643 |
| 1/3   | 1     | 5     | 0.283 |
| 1/7   | 1/5   | 1     | 0.074 |

**Table 4. Judgment matrix B\_3-(C\_5-C\_6) and its consistency test.**

| C \_5 | C \_6 | W    |
|-------|-------|------|
| 1     | 1/5   | 0.167 |
| 5     | 1     | 0.833 |

The CR in each of the above tables is less than 0.1, and it can be concluded that all the judgment matrices have passed the consistency test. Calculate the combined weights of each layer element to the target layer, as shown in table 5.
Table 5. Synthetic weight results.

| Project | C₁ | C₂ | C₃ | C₄ | C₅ | C₆ | C₇ |
|---------|----|----|----|----|----|----|----|
| Weights | 0.062 | 0.028 | 0.007 | 0.555 | 0.042 | 0.210 | 0.097 |

4.3. Comprehensive Analysis

From table 5, the factor layer weights are ranked from high to low: clean and hygienic C₄, strong and durable C₆, interesting interactive C₇, color matching C₁, easy to use C₅, appearance C₂, material Selection C₃. As the cup products have more contact with children’s hands and mouth, the design of children’s smart cup should pay attention to clean and hygienic. Technically, disinfection and sterilization modules can be added. The structure should avoid cleaning dead corners. Combined with the appearance of the shape and material color selection, clean and safe, visual effect clear material should be chosen. Taking into account the physiological and behavioral characteristics of children, the use of smart water cups should be simple and smooth, easy to use, and at the same time blend interesting and interactive, use interesting appearance and interaction to cause children’s drinking interest, and help children develop good drinking habits.

5. Children’s Smart Water Cup Design

By using the Analytic Hierarchy Process to study the design of children’s smart water cup, the extracted design elements are integrated into the conceptual design, as shown in figure 3 below. Tritan is selected as the specified material for baby products in Europe and America, which has the advantages of good hygiene and safety, clear color, simple structure, easy cleaning and convenient use. It is handled by the built-in switch of the cup lid, and the flashing light reminds drinking water. The shape uses three basic figures of square, triangle and circle as the starting point of the design. The square cross-section cup is similar to the beverage package such as yogurt, and the addition of a straw can give children a psychological hint of drinking water. Colors selecting from the three states of water, solid, liquid, gas associated with the corresponding white (snow), blue (ocean), red (flame burning boiling water). There is still a fun and interactive with the cup comes scent stickers, use the “Taste 80% rely on the sense of smell” principle, DIY decoration at the same time for white water flavor.

![Figure 3. Design scheme of children’s smart water cup.](image)

6. Conclusion

The emergence of smart water cup reflects to some extent that people’s perceptions of drinking water have changed. From the guidance of self-awareness to the external reminder, healthy drinking water has gradually gained attention. The design of children’s smart water cup is different from that of adult smart water cup. As a product that has more contact with children’s mouth and hands, its design requires more attention to health and safety, and combined with children’s physiological behavior characteristics, the structure, appearance and safety of children’s smart water cup design has higher requirements. In this paper, the Analytic Hierarchy Process (AHP) is introduced into the design of children’s smart water cup. The design trend is found through market research and patent search, and combined with user interviews, the product of children’s smart water cup is decomposed into indexes
to be evaluated and quantified data. Using AHP to calculate the weight of each index and to order its comprehensive score, to determine the product opportunities, can effectively reduce the interference of scattered factors, quantitative decision-making basis, and improve design efficiency.

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