

Research on Visual Perception of Gender Identification Elements in Water Cup Design

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Abstract. In light of the market trend of using design means to guide enterprise resource allocation in order to improve efficiency, this paper investigates the consumer's gender perception of water cup design elements using morphological analysis and analytic hierarchy process, and verifies the difference of priority among design elements in the process of consumer's perception, and each design element has different influence weights in consumer's gender perception recognition. The research contributes to the transmission of experience in gender-differentiated water cup design and creates efficiency advantages for enterprises competing in the gender-differentiated cup market.

Keywords. Design Elements, Gender Identification, Visual Perception Weight, Analytic Hierarchy Process

1. Introduction

The formulation of industrial design strategies and tactics changes as the goals of different consumer groups change, and gender-differentiated design appears in response to the needs of different genders of consumers [1]. The blue ocean market appears in gender segmentation due to consumption upgrading. Scholars have conducted extensive research in the field of gender elements in order to meet the design requirements of gender segmentation, including product Appearance [2], packaging[3], app interface[4], iPhone games[5], commercial shopping space[6], and other fields. Previous research primarily concentrated on using design to meet the needs of consumers' gender identification, which falls under the category of visual perception effectiveness of design elements.

The current market competition is one of enterprise efficiency, and the winning strategy for small and medium-sized businesses is to create local advantages in the face of overall resource disadvantages. Product design and development will have an impact on the resource allocation of the following links in the commercialization closed loop: production and processing, exhibition, and marketing. With the increase in market competition, the demands for water cups for design in the gender market segment have

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shifted from simply using design means to meet gender visual perception identification to both guiding resource allocation through design means to improve efficiency and assisting enterprises to form local competitive advantages in the gender market segment. Some scholars have expressed interest in using design to guide resource allocation, which falls under the category of visual perception efficiency of design elements [7-8]. Visual attention can only process a limited amount of information from the external environment [8]. Visual perception in graphic representation is independent of the shape and color processing processes [7]. The shape superiority effect in the unconscious processing of graphic visual perception was confirmed by Ke Xue and colleagues' research. Through experiments, Wang Haiyan concluded that the influence of color on the user's search comes before shape in the visual search behavior of icons. Visual elements have different visual perception influence weights in different application scenarios. There is little research on the visual perception priority of product design elements at the moment. How to more efficiently meet the gender identification needs of consumers in water cup design is primarily dependent on the accumulation of individual experience, but there are no verifiable and effective means for the transmission of experience in this field, which severely limits the company's growth. The experiment can verify the priority difference of cup design elements in the recognition of consumers' gender perception, and the design experience in cup gender design can be made explicit, and then optimized and improved, so that the team members' design experience can be combined, and an explicit experience pool can be formed in the field of cup gender design efficiency, to improve the company's ability to optimize resource allocation.

The visual weight research is divided into two steps: determining the constituent elements of the target object and conducting weight sorting experiments on the elements. According to the scene of gender visual perception identification of water cups, the design elements of water cups are first decomposed based on the visual perception characteristics of gender identification, and then the priority among the design elements is compared. Morphological analysis[9] is used in this paper to qualitatively analyze water cup design elements, and a structural model of gender visual perception recognition of water cup design elements is built. Using visual recognition as the measurement standard, the analytic hierarchy process (AHP)[10] is used in the gender recognition of consumers to quantitatively analyze the visual perception weights of the design elements of water cups, and the weight order of the gender visual perception recognition of water cups is formed. In the field of water cup gender identification, the concept of visual perception priority is introduced. By prioritizing design elements, a scientific resource allocation basis is established for the development and design practice, as well as the commercialization of the water cup gender market segment. According to the consumer's habit of recognizing the gender perception of water cups, more support should be given to the design and implementation of elements with high weight, so as to avoid the invisible waste of resource allocation caused by repeated deliberation in the design of elements with low weight of consumers' perception, high requirements for implementation in production, and so on, which will affect the survival of enterprises in an era of fierce competition.

2. Research Path of Weight of Design Elements in Gender Perception Recognition of Water Cup

The research on gender visual perception identification of water cup design elements is carried out in the following steps, as shown in Figure 1: Putting together a set of water cup design elements; Determine the method of evaluation; Perform a hierarchical analysis of the cup design elements.

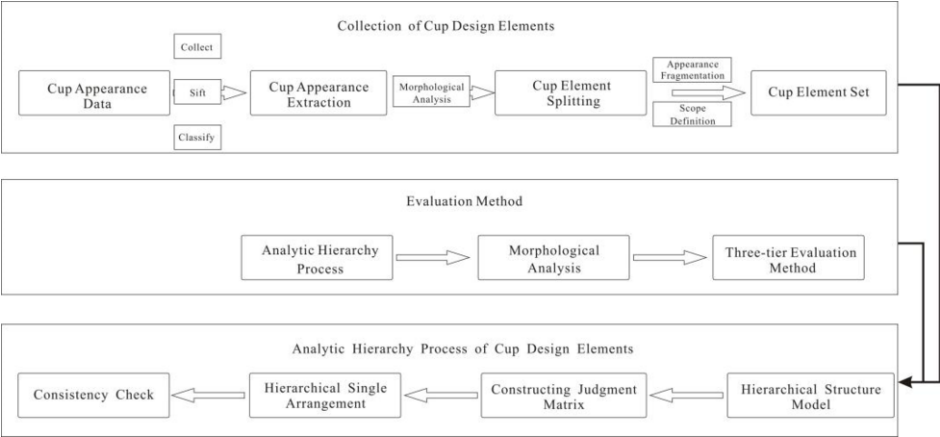


Figure 1. Research Path

2.1. Build a Collection of Cup Design Elements

2.1.1. Cup Collection

A large amount of cup appearance data is required for the research on visual perception weight of gender identification of cup design elements. To begin, the research must collect as many pictures of water cups as possible, then screen the cups with obvious gender characteristics based on the purpose of the research, and finally classify the cup samples based on the visual gender attributes of water cups.

2.1.2. Extraction of Appearance Elements of Cups

Morphological analysis was used to decompose the design elements of cup samples in order to analyze the gender identification of cups from the perspective of design elements. During the implementation process, the research determines the decomposition categories of design elements based on the recognition characteristics of consumers' visual perception, in order to make the design element decomposition methods more in line with the target research needs.

2.1.3. Split and Define Cup Elements

Cup design elements were scattered and reorganized according to categories in order to quantitatively analyze the visual perception characteristics of cups. Specific categories are redefined based on consumer visual perception characteristics. After reorganization, the classified set of design elements of cups is represented as: $X=\{X_1, X_2, \dots X_i\}$, and for the i th element, $X_i=\{X_{i1}, X_{i2}, \dots X_{ij}\}$.

2.2. Determine the Evaluation Method

2.2.1. Morphological Analysis

Morphological analysis was used to decompose the study's design elements. Zwicky, a Swiss-American scientist, proposed morphological analysis in 1942. It is a method that is guided by the concept of systematic search, is based on systematic problem analysis and synthesis, and integrates various factors through a network. Morphological analysis is a powerful creative technique in creationism [11] that can be used for product design and development. It has been used to examine relevant design elements in scenes such as material and product design [12], new textile product design [11], and watch morphological analysis [13]. Morphological analysis is defined by morphologically analyzing things and dividing the research object into some basic components, each with a clear definition and its own characteristics. The basic principle must first define the object to be solved, then divide it into some basic factors and list all possible forms for each factor. Finally, the morphological matrix is established, and various combinations result in several general scheme [14].

2.2.2. Chromatographic Analysis

Chromatography was used to perform the weighted analysis between design elements. Thomas Setty, an American operational researcher, proposed the Analytic Hierarchy Process (AHP). The analytic hierarchy process decomposes the problem into different constituent factors based on the nature of the problem and the overall goal that must be achieved, aggregates and combines the factors at different levels based on the interrelated influence of the factors and the membership relationship to form a multi-level analysis structure model[15], which is mostly applied to the evaluation of product modeling intention[10], green The basic logic of chromatographic analysis is as follows: the problem-related factors are hierarchically structured based on in-depth analysis; starting from the second layer of the model, a proportional matrix is constructed using the pairwise comparison method and a 1-9 scale scale;The maximum eigenvalue λ and the corresponding eigenvector w of the contrast matrix are calculated. The consistency test is carried out by using the consistency index C.I., the random consistency index R.I. and the consistency ratio C.R. .

2.2.3. Three-Tier Evaluation System [16]

To decompose the design elements of the water cup, the experimental morphological analysis method is used, and the analytic hierarchy process is used to analyze the weight of each design element. The highest target layer of the evaluation system, according to the research needs, is cup gender identification; the first-level index layer is a combination of design elements that are redefined and conform to the characteristics of consumers' visual perception; secondary indicators are the selected morphological items under each combination.

2.3. Analytic Hierarchy Process of Cup Design Elements

2.3.1. Establish Hierarchical Structure Model

According to the definition of target layer, first-level index and second-level index in the three-level evaluation system, the hierarchical structure model in the experiment is shown in Figure 2.

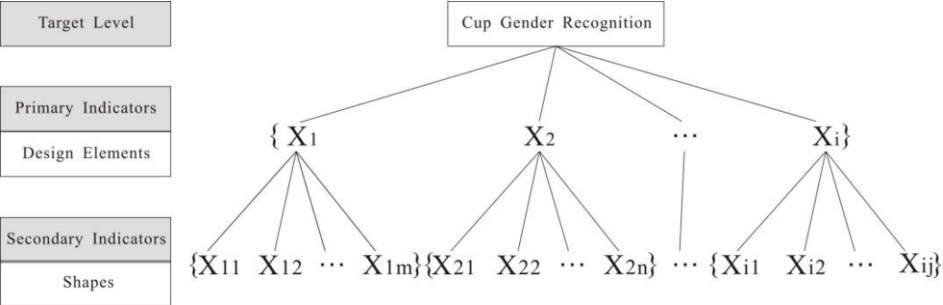


Figure 2. Hierarchical Structure Mode

2.3.2. Construct a Judgment Matrix

The experiment employs the consistent matrix method proposed by Sethi et al., which means that all morphological indexes are compared pairwise rather than together; when comparing, the relative scale is used to reduce the difficulty of comparing different elements and improve accuracy. A_{ij} , the pairwise comparison matrix element, represents the comparison result of the i th factor relative to the j th factor, and the measurement scale assigns importance using Sethi's 1-9 scale [13]. As illustrated in Table 1.

Scale	Meaning
1	Indicates that the two factors are equally important
3	Indicates that one factor is slightly more important than the other
5	Indicates that one factor is significantly more important than the other
7	Indicates that one factor is more important than the other
9	Indicates that one factor is more important than the other
2, 4, 6, 8	Median value of above two adjacent judgments
Reciprocal	The judgment of comparison of factors with i and j is a_{ij} , then the judgment of comparison between factor j and i is $a_{ji}=1/a_{ij}$

Table 1. Metric Scaling

For the target layer, a pairwise comparison judgment matrix $A=(a_{ij})_{n \times n}$ is obtained by the ratio of the relative influence of N elements. The characteristics of the matrix are: $a_{ij}>0$, $a_{ij}=1/a_{ji}$, and when $i=j$, $a_{ij}=1$.

2.3.3. Hierarchical Single Sorting

In a matrix, if $A_{ij} \cdot A_{jk} = A_{ik}$, we call the matrix a consistent matrix.

The consistency index is defined as: $C.I. = \lambda - n/n - 1$.

Where n is the order of the matrix, and λ is the largest eigenvalue of the matrix.

It is difficult to achieve ideal consistency in the real experimental environment because the subjects' backgrounds, perceptions, understanding, and other factors will differ.

The eigenvector corresponding to the largest eigenvalue λ of the judgment matrix is normalized (the sum of all the elements in the vector is 1) and then written as W , $W = \{W_1, W_2, \dots, W_n\}$. As the comparison matrix is not a uniform matrix, Seti et al. suggested that the normalized eigenvector corresponding to its largest eigenvalue should be used as the weight vector, then $AW = \lambda W$.

2.3.4. Consistency Inspection

The random consistency index R.I. is introduced in the experiment to test the consistency of the matrix in the real experimental environment, and the specific R.I. values corresponding to the order of the matrix are shown in Table 2.

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

Table 2. R.I. Values

The consistency ratio is defined as: $C.R. = C.I./R.I.$

When $C.R. < 0.1$, the consistency of the judgment matrix is considered acceptable[13] and can pass the consistency test. Otherwise, it is assumed that the matrix must be rebuilt.

3. Experimental Process

At present, there are many styles of water cups on the market. Considering the market demand and experimental operability, this experiment takes the pop-up cup as the experimental object.

3.1. Pop-Up Cup Material Preparation

3.1.1. Sample Preparation

(1) Sample Collection

In the experiment, pop-up cup keywords were searched on three shopping platforms, yielding a total of 140 pop-up cup products, as shown in Figure 3.



Figure 3. Pop-Up Cup Products

(2) Experimental Treatment of Samples

Three domain experts from Shanghai Houyu Home Design Co., Ltd. with more than five years of design experience were introduced to screen the collected pop-up cups for experiment operability, and 30 object materials remained in the experiment, as shown in Figure 4. The logic of screening is as follows: the visual recognition characteristics of neutral cups are poor, and judgment errors are common.



Figure 4. Object Materials after Screen

As a result, the cups with a neutral overall effect are screened out, leaving only the cups with an obvious visual gender tendency; the purpose of the experiment is to study the weight judgment of design elements from the perspective of consumers, so styles with no obvious difference from the perspective of consumers' perception are merged to leave only the most representative styles.

3.1.2. Decomposition of Design Elements

(1) Functional Morphology Analysis

According to the principle of morphological analysis, list the functional features with visual features in any acceptable range after the water cup is split, as shown in Table 3.

Elements	Functional description
Lid	General term for the top and bottom lids of a pop-up cup
Marble	The button used to control the opening and closing of the lid
Cup Body	General term for the cup's main body
Colours	General term for the colour of the cup body
Material	General term for the body of the cup
Pattern	General term for the various patterns on the cup
Texture	General term for the various textures on the cup
Lid to Cup Connection	Parts connecting lid and cup body

Table 3. The Functional Features with Visual Features

(2) Form Treatment of Pop-Up Cup

The experiment defined the category of element contrast based on the visual characteristics of the pop-up cup shape and expert suggestions. To begin with, because the patterns and textures are not statistical, the visual features of the connection between the lid and the cup usually do not appear in the cup display effect, so the experiment excludes the patterns, textures, and the connection between the lid and the cup. Second, Li wished to divide the appearance design into shape design and CMF design: after decomposition and classification, there is no one-to-one correspondence between the cup body and the lid among the shape elements. There are 5 basic cup body shapes and 8 lid shapes among the 30 types of pop-up cups, and the lid shape and the cup body shape are treated as separate design elements; in the field of design, CMF does not simply list the three, but more importantly, the relationship between color, material, and craft optimizes the final finished effect. Color and material elements are incorporated into texture elements in the experiment. Because the texture of marbles differs clearly from the texture of cups, the texture of marbles and the texture of cups are separated into two distinct elements. Because of the volume comparison, the texture of the cup body is used as the texture element of the cup in the experiment for cups with different body and lid textures.

The morphology of 30 pop-up cups after screening was analyzed, and the morphology analysis table used in the experiment is shown in Table 4.

Elements	Concept Description
Lid Shape	Overall shape of the top and bottom lid of the pop-up cup
Marble Shape	Shape of the button used to control the opening and closing of the lid
Cup Body Shape	The shape of the main body of the cup
Marble Texture	General term for the effect created by the colour, material and workmanship of the marbles
Cup Body Texture	General term for the effect created by the colour, material and workmanship of the cup body

Table 4. The Morphology Analysis Table after Screen

3.2. Experimental Questionnaire Settings

The questionnaire for the subjects is divided into two parts.

The first part is the cup gender orientation test. In order to judge the degree of male and female cup sexual orientation, the degree adopts a five-level system, as shown in Table 5.

Male ☐	5	4	3	2	1
Female ☐	Very Obvious	Relatively Obvious	Average	Moderately Obvious	Fairly Obvious

Table 5.The Questionnaire

The second part is the test of the influence of gender orientation of each design element of each cup, as shown in Table 1.

3.3. Selection of Experimental Subjects

A total of 30 people were tested. Professional designers are skilled at judging in the field of visual perception, but they are also susceptible to thinking patterns. Consumers are prone to cognitive errors in general due to a lack of relevant professional experience. To avoid data deviation caused by thinking patterns and cognitive errors, design students were chosen as subjects, and a small number of professional designers and general consumers were chosen as samples. The final 30 subjects include 20 product art design majors, 5 professional designers, and 5 general consumers with no design background. For the experimental results of a single cup, the geometric average of 30 subjects is used, and for the total experimental results, the geometric average of 30 subjects is used.

3.4. Experimental Process

The experiment was carried out using an offline questionnaire. Allow the subjects to become acquainted with the questionnaire's structure and the meaning of the questions before beginning. After a simple personal data inquiry, the subjects choose the two questions in the questionnaire on their own, without communicating with one another, during the filling stage. Allow the subjects to recall the most impressive style and design elements after filling in the blanks.

3.5. Presentation of Experimental Materials

The modeling elements are wireframed after the texture is removed in the comparative experiment; the texture is presented in the form of equal-volume sample plates. The subjects were given the experimental materials in the form of separate cards for each material object. To improve the effect of pairwise comparison, all pairwise comparison combinations are prepared ahead of time in the experiment, and only the predefined comparison elements are presented each time, as shown in Figure 5. After the subjects finished scoring, they recovered the current set of comparison cards before displaying the next group of comparison objects.

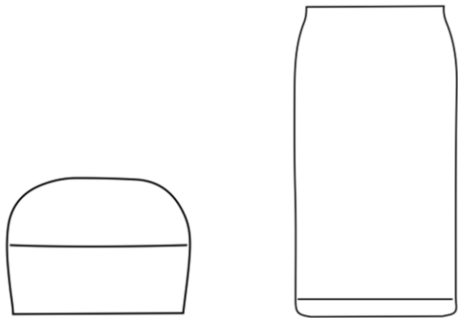


Figure 5. Experimental Materials

3.6. Experimental Data Collection and Analysis

3.6.1. Construction of Hierarchical Structure Model

The experimental hierarchical structure model includes five elements: lid modeling, marbles modeling, cup modeling, cup texture and marbles texture. As shown in Figure 6.

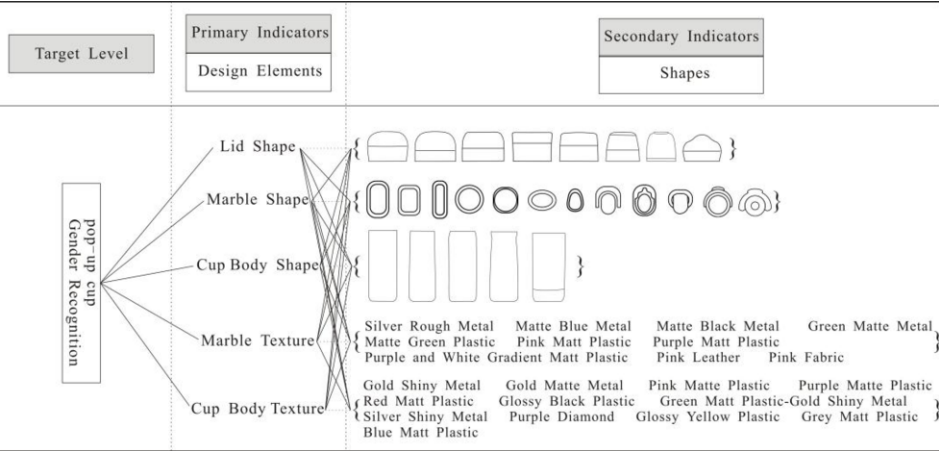


Figure 6. Hierarchical Structure Model

3.6.2. Establish Judgment Matrix

The morphological items of secondary indexes in different primary index design elements were compared pairwise. The morphological items in the same design elements are not compared pairwise because the purpose of the experiment is to compare the visual recognition weights of different design elements. The geometric average of all forms in the set is used to obtain the data between the design elements of the first-level index.

According to the actual needs, 9 is divided into proportional scales, that is, 1, 3, 5, 7, 9, 1/3, 1/5, 1/7, 1/9 are adopted, but 2, 4, 6, 8 and reciprocal are not adopted.

The judgment matrix obtained is shown in Table 6.

	Lid shape	Marble Shape	Cup Body Shape	Marble Texture	Cup Body Texture	Column Vectors	Weighting
Lid Shape	1	1.6564	0.5221	0.4203	0.5040	0.6640	0.1328
Marble Shape	0.6037	1	0.4757	0.3927	0.4050	0.5030	0.1006
Cup Body Shape	1.9152	2.1019	1	1.1108	0.9001	1.2276	0.2455
Marble Texture	2.3792	2.5464	0.9002	1	1.2117	1.3550	0.2710
Cup Body Texture	1.9840	2.4691	1.1110	0.8253	1	1.2503	0.2501

Table 6. The Judgment Matrix

3.6.3. Hierarchical Single Sort

$$\lambda_{\max} = \frac{5.234 + 4.917 + 4.922 + 5.080 + 5.027}{5} = 5.036$$

$$C.I. = \frac{\lambda_{\max} - n}{n - 1} = \frac{5.036 - 5}{4} = 0.009$$

3.6.4. Consistency Verification

$$C.R. = \frac{C.I.}{R.I.} = \frac{0.009}{1.12} = 0.008$$

0.008<0.1, so the experiment meets the consistency requirements.

3.7. Results and Discussion

The experimental data show that texture is the most influential factor in pop-up cup gender identification, followed by cup body, lid, and marble, with the following influencing relationship: Marble Texture> Cup Body Texture> Cup Body Shape> Lid Shape> Marble Shape.

There are two special situations that occur during the experiment: For starters, the influence weights of the same type of element in different cups vary greatly. Reason: Although the cup's composition can be divided into fixed components, the visual focus of the design scheme does not have a fixed relationship with specific elements, which varies depending on the design subject. Second, after shape splitting, the cup with obvious visual focus has no obvious weight tendency in the weight analysis. Reason: The visual focus is the result of the combination and comparison of several design elements. Because the contrast effect of the combination disappears when the design elements are separated independently, the application of morphological analysis in the design field needs to be expanded.

The goal of design is to create intuitive feelings in consumers. As a result, the subsequent study examines the analysis from the standpoint of consumers' feelings, introduces the concept of visual focus to broaden the morphological analysis method, and attempts to divide the range of elements based on the composition of consumers' recognition feelings. Although marbles are small in size, it is easy to form consumers'

visual focus by contrasting design techniques, which has a strong influence on consumers' visual recognition. The visual weight relationship of Marble Texture> Cup Body Texture> Cup Body Shape> Lid Shape> Marble Shape can be interpreted as the importance of establishing the cup's visual focus.

4. Conclusion

In this paper, a structural model of gender perception recognition of design elements is constructed from the perspective of gender perception recognition priority, combining morphological analysis and chromatographic analysis, and a quantitative model is used to describe the corresponding relationship between consumer perception recognition weight and water cup design elements. Water cup experiments show that different design elements have different priorities in product gender perception recognition. The findings indicate that consumers' prioritization of visual perception can be used as a foundation for development. Later on, businesses can allocate resources based on the product design goal and the visual perception weight of design elements within that goal, improving the overall efficiency of product commercialization through design.

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