Study on the Morphological Sensitivity of Children's Companion Robot

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Abstract. This paper takes the children's companion robot as the research object, uses the basic principles of Kansei Engineering and the quantitative I class, explores the correspondence between the consumer's emotional image and the child's companion robot's morphological design elements, in order to facilitate the design process of children's companion robot. This paper constructs the image space of children's companion robot based on user's perceptual appeal and establishes a relationship model between design perceptual image and children's companion robot morphological design elements. A model test of the correspondence between imagery and morphological design elements.

Keywords: Children's companion robot · Morphological elements · Clustering algorithm · Quantified class I

1 Introduction

In recent years, children's companion robots have been used as a service robot. Since 2016, the industry has developed rapidly. Some traditional toy companies and technology companies have successively launched children's companion robots with different functions. In the process of social and economic transformation and development, people's consumption concepts are constantly changing. Traditional toy companies no longer only pay attention to the function and quality of products, pay more attention to whether the products are cared for by human beings, can touch the hearts of consumers, and cause emotional resonance. Therefore, the same is true for the children's companion robot industry. From the change of consumer demand, it can be seen that the core of product innovation design is also changing, and the influence of the perceptual elements of user demand on the design of the robot is gradually increasing. Therefore, it is one of the main development trends of modern product design to explore the products suitable for perceptual appeals driven by the perceptual needs of consumers.

The target users of children's companion robots are children from 0 to 12 years old, and their parents pay attention to investing in children's education. Therefore, companion robots are mainly used to accompany children to learn. However, most children's companion robots design is based on the functional design concept, and the emotional design of the children's companion robots form has not been fully

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developed. Based on the theory of Kansei engineering, this paper takes the morphological image as the research object and uses the quantitative method to explore the correlation between the emotional image and the consumers' morphological design elements and to design the design for subsequent research and product development. To guide the reference.

2 Morphological Image of Children Companion Robots

In the development process of children accompanying robots, the intelligent technology of products has made great progress, the product design concept integrating emotional interaction has always been valued by people. Made in China 2025 emphasizes [1] that the expression of the emotional significance of industrial design should be strengthened while product functional innovation is realized. Children's psychology is relatively simple, and they will have an instinctive curiosity and desire for experience for new things. Good design guidance is conducive to the healthy development of children's physiology and psychology, and children can acquire better learning experience [2]. Therefore, through the analysis of the modeling, color, material and other elements of the accompanied robot for children, the emotional image of children is closely combined with the product form [3], so that it has morphological characteristics in line with the aesthetic and emotional needs of children and can bring them rich memories in childhood.

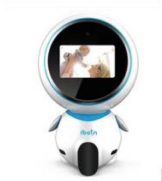
2.1 Determination of Representative Samples

Please This study collects samples through shopping sites, magazines, etc. Such as commercial stores, JD, Taobao, and intelligent robot companies. After the preliminary selection of the research team, 60 product samples were collected. These product samples are then further screened according to the following principles:

1. Consider the rules of the design elements of children's companion robots. Therefore, the selected children's companion robot samples need to cover all the morphological elements and pay attention to the distribution and frequency of each morphological design elements, and the samples need to be typical.
2. Consider the actual situation of the child's companion robot form.
3. Consider the comprehensive evaluation of the research team.

Finally, 21 children's companion robots were selected as samples for research. 16 of them were selected as experimental samples to construct the relationship between sensory image and morphological design elements of children's companion robots, and the remaining 5 models were used as backup samples for test relationships.

Table 1. Representative Samples

1 	2 	3 	4 
5 	6 	7 	8 
9 	10 	11 	12 
13 	14 	15 	16 

2.2 Resolving and Coding Morphological Elements

From the analysis of the components of the child companion robot, 6 elements that have a great influence on the form of the child companion robot are selected from the 9 morphological elements: body contour, display screen, head shape, size, color, and activity mode. Each featured item is further classified and a total of 20 categories are obtained.

According to the principle of the quantified class I, before performing the multiple regression analysis, it is necessary to further quantize the morphological element code values of the representative elements into a matrix containing only "0" and "1". The specific method is: for each category in each feature item, if a sample form factor item

has this category, the category takes a value of "1", and other categories in the feature item take values. As "0", each feature item has one and only one category has a value of "1". For example, if the overall height of the sample is 0–300 mm, the coded quantization value of the "overall size" item is D1 = l, D2 = 0, D3 = 0. According to this principle, the 16 samples morphological design element codes of this experiment were quantified. (see Table 1).

2.3 Resolving and Coding Morphological Elements

This study interviews with professional users such as target users (children aged 3–7 years), parents, designers, etc., as well as from children's books, magazines, corporate websites and brochures on children's products, E-shopping websites, and consumption. A total of 108 emotional vocabularies describing children's companion robots were collected through evaluation and other methods. Through the discussion of the research group, 60 words that are very similar in subjectivity and whose directionality is not clear are excluded, and 60 pairs of sensible words are collected. After the questionnaires on the linguistic temperament of 22 preschool children and the companion adaptability of children's companion robot products, the top 20 pairs of sensible words were obtained. After cluster analysis, four main sensible words were obtained, namely: novelty and interaction. Sex, humanity, and aesthetics. And select words with high semantic meaning as the group has representative vocabulary (Table 2).

Table 2. Image grouping of children accompany robot

The 1st group (Novelty)	The 2nd group (Interactivity)	A 3rd group of (Humanity)	The 4th group (Aesthetic)
Personality – general	Flexible – Inflexible	Amiable - Indifferent	Concise – Complex
Personality – General Innovative - Imitative Interesting – Boring High-end – Low-end Technological – Traditional	Flexible – Inflexible Lively - Clumsy Educational – Mechanical Easy to use - Difficult to use	Safe – Dangerous Warm – Cold Amiable - Indifferent	Soft – Tough Round – Angular Concise – Complex Streamline – Geometric Fashionable – Old Textured - Not textured Light - Steady Lovely – Ugly

3 Questionnaire Survey and Data Processing

3.1 Semantic Differences Questionnaire

Sixteen children's companion robot samples and four pairs of representative vocabulary words have been selected by cluster analysis. This questionnaire survey uses the seventh-order semantic difference method questionnaire. After carefully observing the

sample of the child companion robot given by the test subject, the tester gives a corresponding evaluation value for each pair of perceptual vocabulary according to his subjective feeling. Since the child companion robot of this study is a highly interactive product, the sample picture is provided in addition to the main view, including a side view and a top view, with the necessary text description.

3.2 Selection of Respondents

The questionnaires mainly include the following categories: 1. Parents (purchasing decision makers), children aged 2.3 to 7 years old. Because of the insufficient expression ability of children in this age group, the experimental methods mainly perform an emotional evaluation through vivid description and inductive questions. Only for reference. 3. Professional designers, these people have professional insights on products, they have a deeper understanding of the form of children's companion robots, and have a more professional evaluation. In this questionnaire survey, a total of 90 questionnaires were distributed and 82 were collected. After eliminating the invalid questionnaires with incomplete answers, 77 valid questionnaires were obtained.

3.3 Analysis of the Results of the Perceptual Evaluation

(1) Perceptual evaluation mean
All the valid questionnaires were input into the SPSS statistical software, and the average scores of each pair of sensory sinks were calculated. The results are shown in Table 3 below.

Table 3. Average score of perceptual words

Sample number	Personality – general	Amiable – indifferent	Flexible – inflexible	Concise – complex
1	−0.73	0.82	0.46	0.78
2	0.98	1.12	1.26	−0.76
3	0.66	−0.86	0.46	0.32
4	1.23	0.92	0.26	1.14
5	−0.13	−0.12	−0.68	1.56
6	1.78	1.87	1.12	0.67
7	0.89	0.24	0.12	0.86
8	−0.43	−1.02	−0.89	−0.65
9	−0.22	1.14	−0.57	1.98
10	0.92	−0.12	1.04	0.12
11	−0.32	0.24	0.63	−0.68
12	0.46	0.10	0.22	0.71
13	0.27	0.43	0.86	0.81
14	−0.08	0.23	1.01	−0.11
15	0.34	1.04	−0.82	0.64
16	0.73	0.64	1.06	0.23

4 Construction and Analysis of the Correlation Between Perceptual Image and Morphological Design Elements

4.1 Construction of Correlation Between Perceptual Image and Morphological Design Elements

Codes in this paper, we extracted from design elements and then get a quantitative further quantitative matrix, through a representative sample and semantic vocabulary between perceptual evaluation questionnaire data using SPSS software to calculate the average, each score and form design elements of perceptual image coded values on the basis of the theory of quantification 1 class, enter the multivariate linear regression analysis in SPSS. Among them, the independent variables in the SPSS software is the robot on section sums up the children with the sample quantization matrix form design elements, and the dependent variable is affected by the tester to evaluate each emotional vocabulary scoring average, eventually can be concluded that the children with robot under the perceptual words form design elements of the category scores, the scope of the project, etc., Table 4 is "Personality–Personality" quantification I class analysis results.

Table 4. Results of quantitative class I analysis of perceptual images

	Personality – general	Amiable – Indifferent	Flexible – Inflexible	Concise – Complex
Constant term	0.397	0.417	0.361	0.476
Goodness of fit	0.986	0.838	0.790	0.900
Multiple correlation coefficient	0.993	0.915	0.889	0.947

Generally speaking, when the goodness of fit value is greater than 0.7, the reliability of quantitative I class analysis results can be adopted. Table 5 shows that the goodness of fit value of four pairs of perceptual words is greater than 0.8, indicating that the quantitative I class analysis results have high reliability.

4.2 Construction of Correlation Between Perceptual Image and Morphological Design Elements

1. Category analysis
   The size of the category score represents the degree of correlation between the design category and the semantic meaning of each image. The higher the category score, the closer to the positive sensory image, the lower the score is closer to the negative sensory image. As above, "Personality-Personality", the higher the score, the more the category can express the "Personality" of the emotional image, and the lower the negative score, the more the category shows the opposite "popular" "This emotional image. The values of the categories relative to the vocabulary are listed in Fig. 2.

Table 5. Inductive vocabulary intention table (user rating)

	Personality - general	Amiable - Indifferent	Flexible - Inflexible	Concise - Complex
A1 trapezoid	−0.01	−0.259	−0.411	−0.272
A2 inverted trapezoid	−0.734	0.587	0.49	1.09
A3 round	1.29	0.621	0.219	−0.352
A4 bionic shape	0.229	−0.091	0.281	−0.275
B1 and the eye screen	−0.175	0.982	0.355	0.71
B2 independent display	−0.822	−1.595	−0.805	−0.625
B3 no display	0.965	−0.768	−0.105	−0.95
C1 ball type, elliptical ball type	−0.461	1.139	−0.525	1.317
C2 hemisphere	0.193	−1.037	0.643	−1.415
C3 cuboid	0.155	−0.725	0.156	0.628
C4 irregular type	0.343	0.313	−0.301	−0.255
D1 0–300 mm	−0.708	1.492	0.059	1.809
D2 300–500 mm	0.808	−0.312	0.636	−0.569
D3 500 mm or more	−0.327	−1.397	−1.028	−1.408
E1 black and white gray	0.361	−0.387	0.491	−0.657
E2 partial color	−0.743	0.658	−0.228	0.834
E3 large block color	0.396	−0.193	−0.766	0.142
F1 fixed	−0.5	−1.791	−0.396	−0.787
F2 rotary	−0.587	−0.398	−1.105	−0.031
F3 walkable	0.633	1.052	0.959	0.359

(1) "Personality – general" result analysis
As can be seen from Fig. 1, the "circle" category with the outline line of the fuselage has the highest score of 1.290 and the "Personality" emotional image. The other categories with higher positive scores were "walkable", "screen free", "300–500 mm" in overall size, and "irregular" in head shape, which was closer to the image meaning of "Personality".
Among the negative values of a category, the "independent display" score of the display screen is the lowest, which can best reflect the image of "general". The display screen used for playing video function is set on the fuselage independently and cannot be well integrated with the whole body. It is similar to the tablet computer used in flat time and has no innovation. Negative scores were also lower for "local color", "inverted trapezoid" of the fuselage contour line and "0–300 mm" of overall size, all of which tend to "public" emotional image.

(2) Analysis of the results of "Amiable – indifferent"
As can be seen from Fig. 1, the overall size of "0–300 mm" scores the highest, most able to reflect the "affinity" image. Children under 300 mm are accompanied by small and cute robots, which are in line with the age characteristics of children.

Children can hug and touch, which will give them a closer feeling. In the category negative value, the activity mode "fixed" score is at least −1.791, which best reflects the "indifferent" image. Fixed child companion robots greatly reduce interaction with children.

(3) "Flexible – inflexible" results analysis
As can be seen from Fig. 1, the activity type "walkable" has the highest score and best reflects the "flexible" image. Walkable can track children and increase the interactive experience.
The lowest score in the category negative value is the "rotational" mode of action, which best expresses the "dull" emotional image.

(4) "concise – complex" result analysis
As can be seen in Fig. 1, the overall size of "0–300 mm" scores the highest, the child's companion robot petite body shape can best reflect the "simple" image. Followed by the shape of the head "spherical and ellipsoidal", the head of this shape is more rounded and full, and the lines are smoother. The higher of the positive scores, the two categories of the body contour "inverted trapezoid", "local color" and the display "integrated with the eye screen" are more able to reflect the "simple" emotional image.'

4.3 Construction of Correlation Between Perceptual Image and Morphological Design Elements

The scope of the morphological element refers to the degree of influence of the project on a certain sensible image. The larger the scope of the project, the greater the degree of influence on the image, and vice versa.

As can be seen from Fig. 2, the emotional image of "Personality-mass" has the greatest influence: A fuselage outline (2.024); The minimum influence degree is C head shape (0.804). The "affable – indifferent" perceptual image has the greatest influence: D overall size (2.889); The minimum is A fuselage profile (0.88). The "flexible – inflexible" perceptual image has the greatest influence: Factivity mode (2.064), and the smallest: A fuselage contour line (0.901). The "concise – complex" perceptual image has the greatest influence on the overall size of D (1.809) and the least influence on the active mode of F (0.359). Under this perceptual image, the range value of each item exceeds 1, and there are three values exceeding 1.5, namely: B, display screen, C, head shape, and D, overall size. Therefore, in the design of "concise – complex" perceptual image of children accompanied by robots, the three categories should be considered in the form design.

In summary, it can be found that the main impact items under different perceptual images and the degree of influence of each item are different. According to the following table, corresponding design suggestions can be provided for different positioning products.

5 Establish a Correspondence Model Between Emotional Image and Morphological Elements and Verify

5.1 Establish a Correspondence Model Between Emotional Image and Morphological Elements

The morphological design element of the child companion robot is the independent variable, and the perceptual evaluation value is the dependent variable, and the corresponding relationship model can be established:

$$\begin{aligned} Y = {} & \alpha A1A1 + \alpha A2A2 + \alpha A3A3 + A4A4 + \alpha B1B1 + \alpha B2B2 + \alpha B3B3 + \alpha C1C1 \\ & + \alpha C2C2 + \alpha C3C3 + \alpha C4C4 + \alpha D1D1 + \alpha D2D2 + \alpha D3D3 + \alpha E1E1 + \alpha E2E2 + \alpha E3E3 \\ & + \alpha F1F1 + \alpha F2F2 + \alpha F3F3 + a \end{aligned} \tag{1}$$

In Eq. 1, Y is the perceptual image score value; A1, A2,…, F3 are the morphological design elements (A represents the fuselage outline, B is the display screen, C is the head shape, D is the overall size, E For color, F is the active mode), corresponding to the various categories in the class I theory; αA1, αA2….αF3 is the correlation coefficient of each design element, corresponding to various categories of points; a is a constant term value, Used to adjust the error.

According to the analysis results of the corresponding perceptual images in Fig. 1, the regression relationship model between the four images semantics and the morphological design elements can be established:

(1) The regression relationship model between "Personality-popular" and morphological elements

$$\begin{aligned} Y1 = {} & -0.010A1 - 0.734A2 + 1.290A3 + 0.229A4 - 0.175B1 - 0.822B2 + 0.965B3 \\ & - 0.461C1 + 0.193C2 + 0.155C3 + 0.343C4 - 0.708D1 + 0.808D2 - 0.327D3 + 0.361E1 \\ & - 0.743E2 + 0.396E3 - 0.500F1 - 0.587F2 + 0.633F3 + 0.397 \end{aligned} \tag{2}$$

(2) Regression relationship model between "affinity-indifferent" and morphological elements

$$\begin{aligned} Y2 = {} & -0.259A1 + 0.587A2 + 0.621A3 - 0.091A4 + 0.982B1 - 1.595B2 - 0.768B3 + 1.139C1 \\ & - 1.037C2 - 0.725C3 + 0.313C4 + 1.492D1 - 0.312D2 - 1.397D3 - 0.387E1 + 0.658E2 - 0.193E3 \\ & - 1.791F1 - 0.398F2 + 1.052F3 + 0.417 \end{aligned} \tag{3}$$

(3) Regression relationship model between "flexible-dull" and morphological elements

$$\begin{aligned} Y3 = {} & -0.411A1 + 0.490A2 + 0.219A3 + 0.281A4 + 0.355B1 - 0.805B2 - 0.105B3 \\ & - 0.525C1 + 0.643C2 + 0.156C3 - 0.301C4 + 0.059D1 + 0.636D2 - 1.028D3 + 0.491E1 \\ & - 0.228E2 - 0.766E3 - 0.396F1 - 1.105F2 + 0.959F3 + 0.361 \end{aligned} \tag{4}$$

(4) The regression model of "simple-complex" and morphological elements

$$\begin{aligned} Y4 = &-0.272A1 + 1.090A2 - 0.352A3 - 0.275A4 + 0.710B1 - 0.625B2 - 0.950B3 \\ &+ 1.317C1 - 1.415C2 + 0.628C3 - 0.255C4 + 1.809D1 - 0.569D2 - 1.408D3 - 0.657E1 \\ &+ 0.834E2 + 0.142E3 - 0.787F1 - 0.031F2 + 0.359F3 + 0.476 \end{aligned} \tag{5}$$

5.2 Verification

In order to verify whether the relationship model obtained by multiple linear regression can accurately predict the emotional image of the product, the five selected samples (as shown in Table 6) are verified, and then the verification values of the perceptual evaluation and the regression relationship model are performed. Paired sample T test to verify the credibility of the above regression relationship model.

Table 6. Verify product samples

1	2	3	4	5
				

The semantic difference method questionnaire was distributed to 50 target users, and they were asked to evaluate the four pairs of perceptual vocabulary again. Then, the average of 5 samples in four pairs of perceptual vocabulary was calculated. Finally, the author will have 5 verification samples. The resulting average of the sensory image is compared with the predicted value calculated by the regression relationship model. The two sets of data were entered into the SPSS software and then paired with a sample T-test, which is the result of the final test.

As can be seen from Table 7, the significance of T-test for paired samples of the four pairs of perceptual vocabulary is greater than 0.05, indicating that there is no significant difference between the calculation results of the relationship model and the subjective evaluation of consumers, that is, the four relationship models have a high degree of credibility. In the product design and development of children's companion robot, the emotional image of consumers can be substituted into the above relationship model to obtain the prototype design for the category purpose under the project of each element of the product.

Table 7. Paired sample T test results

Paired sentimental imagery	t	df	Sig. (bilateral)
Couple1 Y1(Personality – general)	0.338	4	0.753
Couple2 Y2(amiable – indifferent)	0.039	4	0.971
Couple3 Y3(flexible – inflexible)	−1.512	4	0.205
Couple4 Y4(concise – complicated)	1.064	4	0.347

6 Summary

Perceptual image and form design elements of the relationship between children with robot model: after the screening of children with robot sample and perceptual image spatial relation between the semantic difference method, questionnaire survey, in using the theory of quantification I kind of questionnaire on the basis of statistical analysis, obtained the related category score, range, constant term, multiple correlation coefficient and goodness of fit, established the corresponding relationship between perceptual image and form design elements of multiple regression analysis model. The specific conclusions are as follows:

"Personality – general" perceptual image: the three morphological design elements of the fuselage contour "circle", "no display screen" and the overall size "300–500 mm" have made the largest positive contribution to the "Personality" image of the child-accompanying robot; The largest contribution to the "public" image is the "independent display" of the display screen and the overall size of "0–300 mm".

"Affinity-indifferent" emotional image: the display "with the eye screen", the head shape "spherical ellipsoid" and the overall size "0–300 mm" scores three of the positive values That is, these three morphological design elements contribute the most to the "affinity" image of children's companion robots; while the "indifferent" intentions contribute the most: the display "independent display" and the activity mode "fixed" Category.

"Flexible – Inflexible" emotional image: the head shape "hemisphere type", the overall size "300–500 mm" and the activity type "walkable" three categories are positively ranked three, that is, these three forms The design elements contribute the most to the "flexible" imagery of the children's companion robots; the most important contribution to the "dull" imagery is the overall size "more than 500 mm" and the active mode "rotary".

"Concise –Complex" emotional image: the body contour "inverted trapezoid", the head shape "spherical ellipsoid" and the overall size "0–300 mm" are three of the positive values. That is to say, these three morphological design elements contribute the most to the "concise" image of the children's companion robot; the two items that contribute the most to the "complex" image are the head shape "hemisphere type" and the overall size "500 mm or more". Head.

Correspondence model test between perceptual image and morphological design elements: 50 subjects were selected again to evaluate the sensitivity of five children's companion robot verification samples, and the predicted values of subjective evaluation mean and verification sample morphological elements were substituted into the relationship model. A paired sample T-test analysis was performed, and the results showed that the relational model had a high degree.

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