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Improvement Design of Household Medical Nebulizer for Children Based on Ergonomics

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ABSTRACT

The purpose of this paper is to study the user needs of household children's nebulizers from the perspective of Ergonomics, and to provide a basis for the improved design of products, so as to help children carry out nebulization treatment more efficiently and safely. The user research method was used to analyze the pain points and needs of users in the use of children's home nebulizers. Through the literature research, this paper studied the relevant human-machine size and psychological characteristics of children were, and discussed the demand-orientation of children's nebulizer shape, color and material were. Through the above research, this study analyzed the needs of children's nebulizers in terms of the experience of use and man-machine dimensions, and improved the product. The improved design of household children's nebulizers could not only soothe children's anxiety in the treatment to a certain extent, but also promote children's healthy growth and help improve the system of children's household medical products.

Keywords: Children's nebulizers, Household medical product design, Ergonomics

INTRODUCTION

Respiratory diseases are one of the most prevalent diseases affecting children around the world and an important cause of rising child mortality (M. Saleh and M. Çevik, 2022). Nebulization therapy is the most common treatment for children with respiratory illnesses (X. W. Liu et al., 2022). Compared to drug and injection delivery methods, nebulized therapy has the advantages of smaller doses, fewer side effects and simple operation. Through literature research, this paper found that most children's nebulizers were not significantly different from adult nebulizers (Y. X. Zhao, 2021), which do not meet the physical and psychological needs of children.

For the innovation and improvement of children's nebulizers, Jia Anmin and Sun Wei (2020) have analyzed the current situation of nebulizer products and children's psychological characteristics. Shi Yaojun (2018) has explored the integration of bionics into the emotional design of medical products. Xu Xiaowang (2020) has proposed two design principles of product Ergonomics and interactivity. Based on narratology and narrative design theories, Zhang Kai and Gao Zhenyu (2018) have investigated how to enhance children's

emotional experiences in the course of therapy. Cao et al. (2022) have pointed out that common nebulizer designs ignore children's psychological needs and user experience. They proposed a design scheme that integrates cartoon images and music into products.

In general, most of the research focuses on user experience and technical optimization of children's nebulizers, with less practice in improving the human-machine dimensions and interactions for children's household nebulizers. This study adopted the user survey to analyze the pain points and demands of users in the use of nebulizers. Took Ergonomics as the main entry point, the nebulizer was more compatible with the physiological and psychological needs of children, and optimized the existing children's nebulizers.

RESEARCH PROCESS

Nebulizers for children are usually used with the assistance or supervision of parents. Therefore, the main subjects of this study were children and parents who used nebulizers. There are two parts of user research: an online questionnaire was used to analyze the potential needs of users and collect users' expectations for the improvement of household children's nebulizers. Another method was offline user interviews to explore the problems existing in the use of atomizers, and to provide references for the subsequent improvement of product Ergonomics.

Questionnaire Research

The respondents were parents of children aged 12 and under, the valid sample was 23. This questionnaire provided information about the problems

Table 1. Questionnaire results.

Dimensions	Questionnaire results	Design conclusions
User information	The majority of children using nebulizers were 0 to 6 years old.	1) The size of children's nebulizers should conform to Ergonomics for children. 2) The structure of children's nebulizers needs to be simplified. 3) Focus on emotional design in the appearance of children's nebulizers.
Usage rate	Over 70% of parents had used children's nebulizers.	
Usage process	More than 75% of children showed uncooperative behavior during nebulized treatment. When the child was 0 to 3 years old, over 60% of parents helped children to hold the nebulizer; by the age of 4 to 6 years, this fraction dropped to 7.69%.	
Product preference	60.87% of parents chose handheld nebulizers.	
Expectation	Lightweight, easy-to-use and child-friendly.	

Table 2. User interview results.

Basic information	Children's age	Children using nebulizers were mostly between 1 and 4 years old.
	Treatment site	Most parents purchased household nebulizers and reflected that home treatment was more convenient than hospitals.
	Nebulization type	Most parents chose the compression mask type.
	Accompaniment	Most children needed to be accompanied by their parents. Some parents reflected that children could complete independently.
Highlighted issues	Children's emotion	Most children had resistance to the first use of nebulizers.
	Man-machine size	Most parents did not have a clear understanding of the size of the mask, and usually used masks uniformly distributed by hospitals or ordinary nebulizer masks on the market. But the size of these masks was mostly based on adults, which was inconsistent with the face of children.
	Product appearance	Most of the children's nebulizers were medical styles, and the design does not conform to the psychological characteristics of children.

with children's home nebulizers in five areas: user Information, usage rate, usage process, product preference and user expectation. Table 1 shows the summary of the questionnaire.

User Interviews

The user interviews were conducted in the primary school and kindergarten affiliated with Huazhong University of Science and Technology. Ten parents (7 mothers and 3 fathers) and five children (3 females and 2 males) were randomly selected as interviewees.

Based on the above analysis, five requirements are summarized (Table 3).

Table 3. Requirements for household children's nebulizers.

	Project	Demand
1	Visual Experience	Meet the emotional needs of children
2	Man-machine size	Fit the physiological characteristics of children
3	Interaction	Add interest to human-machine interaction
4	Functional use	Enhance visibility of use and treatment progress
5	Product structure	Appropriate simplification

ANALYSIS OF THE PHYSICAL AND PSYCHOLOGICAL CHARACTERISTICS OF CHILDREN

Physiological Characteristics Analysis

Based on the previous research, this study identified the analysis object of human-machine size as 4 ~ 6 years old children. The gripping method of nebulizers was forceful grasp. The larger the contact area between the handle and the palm, the lower the compressive stress (Z. Y. Lv and Y. Qu, 2013). The related hand size was taken from the 95th percentile of males aged 4 to 6 years. According to the analysis, the functional correction of hand width is 27 mm, and the functional correction of hand length is 45 mm. Following the formula in Table 4, the thumb width and the fingertip distance in the tiger mouth were calculated in Table 5. (The dimensions were based on the Chinese National Minor's Hand Size Typology.) Combined with the Head and face dimensions of children in Table 6, the relevant dimensions for the nebulizer were calculated and collated to give Table 7.

In terms of grasping shape, the near-elliptical or polygonal handle was more suitable for the human hand, which could reduce the pressure on the palm, and the grasping state is the most ideal (Z. Y. Guo, 2021). For this reason, the nebulizer handle could adopt a near-elliptical shape, which is more conducive to children.

Table 4. Calculation formula of hand control part (GB/T 26159-2010).

Control parts	Male	Female
	Regression equation	Regression equation
Ring finger length	$Y=-1.42+0.413X_1$	$Y = 1.25+0.399X_1$
Pinky length	$Y=-1.64+0.328X_1$	$Y=-0.72+0.321X_1$
Hukou middle finger fingertip distance	$Y = 10.98+0.645X_1$	$Y = 14.84+0.613X_1$
Proximal width of the index finger	$Y = 2.79+0.199X_2$	$Y = 2.40+0.203X_2$
Distal width of the index finger	$Y = 3.05+0.168X_2$	$Y = 2.72+0.173X_2$
Wide knuckles of the thumb	$Y = 4.14+0.200X_2$	$Y = 3.10+0.209X_2$

Note: X_1 is the hand length, X_2 is the hand width, and Y is the size of other parts of the hand.

Table 5. Hand size of children (in mm) (GB/T 26158-2010).

Parameter	Male (4~6 years old)			Female (4~6 years old)		
	5	50	95	5	50	95
Hand width	49.6	58.1	63.5	48.4	56.6	61.8
Hand length	105.4	123.2	134.6	104.7	122	133
Thumb width	14	15.8	16.8	13.2	14.9	16
Hukou middle finger fingertip distance	78.9	90.4	97.8	79	89.6	96.4

Table 6. Head and face dimensions of children (in mm) (G. Y. Zhang, 2020).

Project	Average value (mm)	Standard deviation (mm)
Head full height	203.8	12.2
Head length	174.7	7.2
Head width	151.8	6.0
Head circumference	512.5	19.5
Morphological length	94.9	6.2

Table 7. Sizing reference for children's household nebulizers.

	Parameter	Size
1	Body size (handheld part)	Length<=90mm, Diameter<=57mm
2	Button size	Diameter: 16~18mm
3	Mask size (G. Y. Zhang, 2020)	Mask midpoint to bridge of the nose: 60mm Midpoint to chin: 36mm Midpoint to side cheek: 50mm Delivery port diameter: 18mm, vent diameter: 9mm

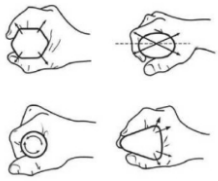

Figure 1: Different handle cross-sectional for gripping (Z. Y. Guo, 2021).

Psychological Characteristics Analysis

Children's Perception of Color

Vision plays an important role in children's cognition. Children after the age of four can produce emotional changes according to the different colors of things. Brilliant colors will arouse children's strong interest. According to research, children's favorite color groups in early childhood are orange, yellow, red and green (Z. X. Zhu, 2000). With the increase of age, children's aesthetic of color is gradually established. Therefore, choosing the right color in the process of designing products can make children higher accepted.

Children's Perception of Form

Children's shape perception develops rapidly. At this stage, children can distinguish basic geometric shapes such as circles, squares and triangles, and gradually form self-aesthetic evaluation (J. H. Liu, 2013). Furthermore, children often associate geometric shapes with figurative objects. For the images of animals and plants, Children are more receptive and friendly (B. J. He, 2019). Therefore, the appearance of children's medical products should be

lively and close to the specific form of nature, so as to reduce children's resistance.

DESIGN PRACTICE

This study chose the cartoon fox that often appears in fairy tales as the main body of the product, because the fox could make children think of nature and lovely, and easy to be accepted by children. In terms of shape, rounded surfaces were mostly used, which could give people a close and soft feeling, and also prevent children from being hurt during the use of the product. In terms of color, bright orange and warm white were used as the main colors of the original product, which could convey a warm feeling. In terms of material, this design was mainly made of ABS plastic and silicone, with a skin-friendly and flexible frosted texture.

Combined with literature research, this study found that mask nebulizers were more effective than nebulizers such as oral inhalers and nasal cannulas (G. Y. Zhang, 2020). Therefore, this solution adopted a mask whose scale was standardized according to the child's human dimensions to ensure the efficiency of the nebulized treatment. In addition, the contour of the mask fitted the child's face, which could reduce discomfort during the use of the nebulizer.

Figure 2: Nebulizer body (left), Nebulizer masks (right).

This study improved the reminder function of the nebulization treatment time. As the nebulization time progressed, the fox's ears closed slowly from the initial opening (Fig. 3). When the nebulization treatment was finished, the

Figure 3: Ear position while nebulization is in progress (left), ear position at the end of nebulization (right).

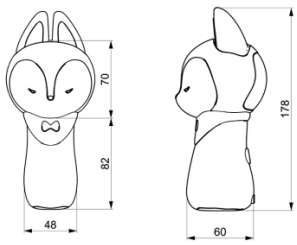

Figure 4: Nebulizer size (in mm).

ears closed completely and a short beep sounded. This design could not only increase children's interest in the treatment process, but also reduce the anxiety caused by children's inability to visually understand the process. Figure 4 shows the size of the children's handheld nebulizer.

CONCLUSION AND LIMITATION

According to the questionnaire survey, user interview and literature analysis, the pain points and users' needs were explored, and later a new kind of children's household nebulizer was designed based on Ergonomics. The new design product was helpful to alleviate children's anxiety, and greatly improved the treatment efficiency which promoted the children's health. This study had achieved certain research results, but there are many shortcomings, below:

1) The scope of user research around the school was limited and the sample was not sufficient. This study needed to broaden the scope of the user research and increase the sample in subsequent refinement.
2) The design was not physically modeled to observe problems in actual use, and further model testing needed to be refined in the future.
3) The problems raised in this paper were limited, and the relationship between appearance and function needed to be further studied in the future to summarize the problems more comprehensively.

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