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One-Handed Disabled Product Design Based on CJM-KANO-AHP User Need Model

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ABSTRACT

One-handed disabled encounter many inconveniences in life. In order to help designers focus on the high-priority needs of the one-handed disabled and avoid the subjectivity of needs selection in product design, a product design method based on CJM (Customer Journey Map)-KANO (KANO Model)-AHP (Analytic Hierarchy Process) user need model for one-handed disabled is proposed. Firstly, the user needs of the one-handed disabled are collected comprehensively by CJM which helps to collect multi-scene needs. Secondly, the collected needs are classified according to the KANO model, needs are classified into must-be needs(M), one-dimensional needs(O), attractive needs(A), indifferent needs(I), reverse needs(R), and questionable needs(Q). And only the first three types of needs are retained. Thirdly, the user need hierarchy analysis model is constructed based on the AHP method, matrix judgment, weight calculation, and consistency check are conducted for the retaining needs ranking. Finally, the one-handed washboard was designed for addressing the first priority ranking need of the one-handed disabled. The user need model based on CJM-KANO-AHP is applied in the product design process of one-handed disabled, which effectively solves the problem of multi-scene need collection and need prioritization. Compared with the existing methods that only rank the relatively limited number of needs in a single scene, our method ranks needs within the scope of multi-scene for the one-handed disabled which has more practical significance. It also provides ideas for similar product design processes.

Keywords: CJM, KANO, AHP, One-handed disabled, Need ranking, Product design

INTRODUCTION

According to the estimation of the World Health Organization (WHO), the number of disabled people in the world has exceeded 1 billion, accounting for 15% of the world's population (Ai, 2013). The total number of disabled people in China is 82.96 million, of which 24.12 million are limb disabled, accounting for 29.07% of the total number of disabled people (Chen et al., 2011). One-handed disabled is a typical group people of limb disabled. They only have one healthy hand, and the other hand or joint arm is amputated or dysfunctional. The acquired one-handed disabled can also be divided into two categories: the remained hand is the dominant hand or the non-dominant hand (Liu, 2012). The inconveniences of one-handed disabled exist in the multi-scene of life. The number of needs is large and the scenes involved are complex, so it is impossible to meet all the needs because of cost and other reasons. At the same time, focusing on high-priority needs at the beginning of design development is one of the key factors for the success of the final new product development (Ren, 2008). Therefore, in order to help designers focus on the high-priority needs of the one-handed disabled, we need to first solve the problem of comprehensively collecting the needs of the one-handed disabled, and then solve the problem of prioritizing the needs.

RELATED WORK

The researches on the one-handed disabled product design can be generally divided into two categories. The first category is to put forward design theories for the one-handed disabled according to their characteristics, for example, they may not be able to complete movements with both hands, lack strength, or lack balance. Wang et al. (2018) proposed a one-handed barrier-free product design method based on the humanized design theory. Jia (2016) proposed a design theory for the one-hand disabled based on universal principles of design. Yang (2014) proposed a barrier-free design procedure for hand-assistive devices. Priya et al. (2021) proposed the development process and method of one-handed disabled assistance products based on desktop manufacturing methods (additive manufacturing/3D printing, laser cutting, and CNC processing). The second category is practical research for the one-handed disabled product design. Karlson et al. (2008) studied the interaction design of using small devices with one hand, including thumb movements, device applications, searching, and other typical problems. Parhi et al. (2006) studied the size of small screen devices operated by one hand thumb. Yu et al. (2013) studied and designed the auxiliary interface of the one-handed handheld device, and finally solved the problem of quickly and accurately clicking on the area that could not be reached with the thumb before with the least amount of attention. Karlson et al. (2006) studied the basic problems in the interaction design of one-handed mobile devices and provided a basic knowledge of user behavior and preferences, as well as the future research trends in the interaction design of one-handed mobile devices. Nagendran et al. (2021) investigated the one-handed disabled keyboard, including commercially available and patented one-handed input devices, and finally proposed their own future design direction. To sum up, the existing researches mainly propose a one-handed product design theory or practical research on a specific one-handed design issue. However, the above two categories of researches do not pay enough attention to how to select the high-priority needs of one-handed disabled for product design.

To solve the above problem, it was learned that the models frequently used in modern design researches to determine needs or calculate the need weight are the KANO Model(KANO), Quality Function Deployment(QFD), Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to an Ideal Solution(TOPSIS), Theory of the Solution of Inventive Problems (TRIZ), etc (Zhao et al., 2021). Liu et al. (2018) classified user needs using the KANO model and then used QFD to convert user needs into design elements to calculate the user need priority. Kong et al. (2019) proposed a KANO-based product innovation need screening method to reduce the subjectivity of designers in need screening. Zhou et al. (2020) used AHP for weight calculation, consistency check, and need priority ranking. In addition, many scholars complement these methods to address the analysis and processing of needs. However, the models available in the literature mostly address the range of needs for a defined scene such as a one-handed disabled bathing process, or a defined product such as an elderly household companion robot about its multiple design metrics. The range of needs is closed and limited. However, the high-priority needs of the one-handed disabled may exist in a wide range of life scenes, it has more practical significance to address the problem of priority ranking the needs of the one-handed disabled in the context of open, multi-scene need ranges.

CJM-KANO-AHP USER NEED MODEL

CJM (Customer Journey Map) is a tool to visually represent user behavior in real environments, it helps respondents objectively and effectively recall the intersection of behavioral activities and target collection needs over various periods, and guides respondents to output the needs of the one-handed disabled in an all-around way. After user need collection, the KANO model is a good way to scientifically classify user needs by attribute (Hu et al., 2020). However, in order to determine the priority of needs and find the focus of the design, after the need classification, we need to further calculate the user needs weight and rank the needs. AHP is a frequently-used and mature method for demand prioritization, it has been used in the demand ranking of tourist souvenir design (Yang, 2017) and furniture design (Zhao et al., 2022). The AHP method, based on expert scoring and one-by-one comparison, is a multi-criteria decision-making method that combines qualitative and

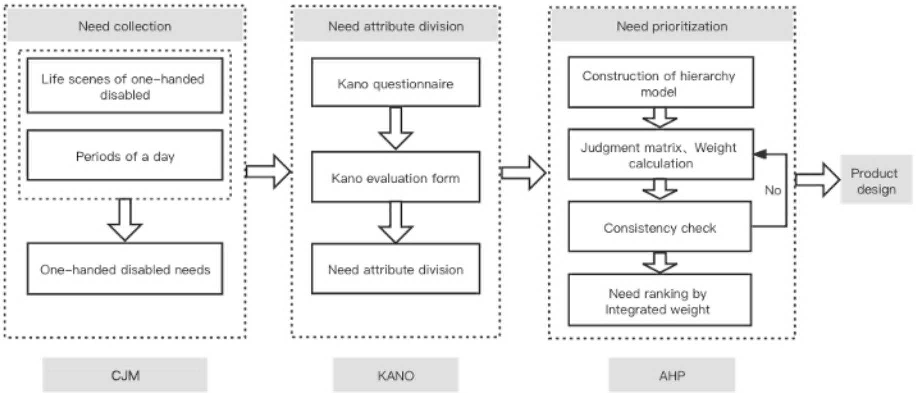

Figure 1: The research framework of CJM-KANO-AHP user need model.

quantitative aspects, it also has the advantage of being objective and systematic, simple and practical (Zhao et al., 2021). The KANO model can provide a hierarchical division basis for the AHP method, and the AHP method can calculate the weight for the needs divided by KANO. Therefore, CJM, KANO, and AHP are combined to construct a user need model to solve the problem of judging the high-priority needs in multiple scenes during the product design for the one-handed disabled. The research framework is shown in Figure 1.

NEED COLLECTION BASED ON CJM

First, we collected needs using the CJM approach. In order to get a more realistic understanding of the actual needs of the one-handed disabled, 36 one-handed disabled respondents with hemiplegia and one upper limb amputation were randomly recruited at the rehabilitation center for the disabled. Using the CJM approach to design the needs collection questionnaire (see Table 1). The vertical axis of the table is the eight periods of a whole day, and the horizontal axis of the table is the scenes where the behavioral difficulties of one-handed disabled appear and the products are used: clothes wearing and washing, cooking and eating, entertainment and learning, personal hygiene (Wang et al., 2018). This questionnaire was designed to help respondents recall what inconveniences and needs they would encounter in every period of each scene. Combining the dimensions of multiple scenes promotes the comprehensiveness of needs collection. Finally, among the 36 questionnaire results received, we combined the duplicate needs and then obtained a total of 33 one-handed disabled user needs (see Table 2).

Table 1. Questionnaire on the need collection of the one-handed disabled.

Life scenes / Periods of a day	Clothes wearing and washing	Cooking and eating	Entertainment and learning	Personal hygiene
Early morning : 1:00 ~ 5:00				
Morning : 5:00 ~ 8:00				
Forenoon : 8:00 ~ 11:00				
Noon : 11:00 ~ 13:00				
Afternoon : 13:00 ~ 17:00				
Evening : 17:00 ~ 19:00				
Night : 19:00 ~ 23:00				
Midnight : 23:00 ~ 1:00				

NEED ATTRIBUTE DIVISION BASED ON KANO MODEL

The user needs are classified by attribute according to the KANO questionnaire results and the KANO evaluation form. According to the KANO questionnaire, the 33 user needs were asked in two dimensions, positive and negative. Respondents were asked about their satisfaction toward addressing this need and not addressing it, and satisfaction was classified into five levels (like, expect, neutral, live with, dislike) using Likert five-point scale. We distributed 106 questionnaires and got 97 valid questionnaires by recruiting one-handed disabled in disabled rehabilitation centers, nursing homes, and online. The results of the KANO questionnaires were analyzed using the KANO evaluation form and the user needs were classified into six types:

Table 2. Result of the need collection of the one-handed disabled.

No.	Needs	No.	Needs	No.	Needs
N1	Tie shoelaces	N12	Wash vegetables	N23	Exercise
N2	Put on or take off clothes	N13	Cut vegetables	N24	Eat with chopsticks
N3	Wash hands	N14	Wash dishes	N25	Squeeze toothpaste onto the toothbrush
N4	Zip up a zipper	N15	Hang wet clothes	N26	Wring out water
N5	Fasten buttons on clothes	N16	Use a ruler	N27	Use a dustpan
N6	Tie a leather belt	N17	Use a camera	N28	Tie garbage bags
N7	Unscrew a bottle cap	N18	Unplug the plug on the socket	N29	Tie up hair
N8	Peel fruits	N19	Use a game handle	N30	Handwash something
N9	Peel eggshell	N20	Carry heavy objects	N31	Take a bath
N10	Open packing bags	N21	Write with the non-dominant hand	N32	Move a large basin of water
N11	Put a glove on the healthy hand	N22	Use scissors with the non-dominant hand	N33	Cut fingernails for the healthy hand

Table 3. One-handed disabled need attribute analysis.

Need No.	Number of people						Attribute	Need No.	Number of people						Attribute
	M	O	A	I	R	Q			M	O	A	I	R	Q	
N1	9	18	20	45	4	1	I	N18	3	7	23	43	1	20	I
N2	82	6	2	7	0	0	M	N19	8	25	56	5	0	3	A
N3	34	24	14	20	5	0	M	N20	11	25	35	23	3	0	A
N4	12	29	37	19	0	0	A	N21	19	6	22	50	0	0	I
N5	12	16	28	39	0	2	I	N22	14	8	25	48	1	1	I
N6	15	12	21	49	0	0	I	N23	11	14	21	29	8	14	I
N7	9	17	23	47	0	1	I	N24	2	13	23	45	12	2	I
N8	13	14	29	41	0	0	I	N25	9	12	20	45	2	9	I
N9	7	12	33	43	0	2	I	N26	37	25	18	13	1	3	M
N10	9	12	23	53	0	0	I	N27	16	7	33	39	0	2	I
N11	7	16	18	23	15	18	I	N28	18	5	27	44	0	3	I
N12	25	37	24	11	0	0	O	N29	13	6	23	53	0	2	I
N13	25	37	20	14	1	0	O	N30	67	15	10	5	0	0	M
N14	70	10	11	6	0	0	M	N31	7	40	27	23	0	0	O
N15	15	36	25	20	1	0	O	N32	19	39	27	12	0	0	O
N16	3	12	13	53	0	16	I	N33	21	19	27	29	0	1	I
N17	2	12	23	50	5	5	I								

must-be need(M), one-dimensional need(O), attractive need(A), indifferent need(I), reverse need(R), and questionable need(Q) (see Table 3). Finally, indifferent needs, reverse needs, and questionable needs were excluded, and the must-be needs, one-dimensional needs, and attractive needs are retained for the next stage of AHP user needs weight analysis.

NEED WEIGHT ANALYSIS BASED ON AHP

Based on the analysis result of the KANO model, Judgment matrix construction, need weight calculation, and consistency check were performed using the AHP method. As shown in Figure 2, the target layer is the one-handed disabled needs, the criteria layer is must-be need, one-dimensional need, and the attractive need, while the specific needs under these three attributes of needs are expanded to the sub-criteria layer. With X denoting the target layer, M denoting the must-be need in the criteria layer, its expanded sub-criteria layer M1 indicates put on and take off clothes, M2 indicates wash hands, M3 indicates wash dishes, M4 indicates wring out water, M5 indicates handwash something, and so on. The AHP user needs questionnaire with the 1–9 scale proposed by Saaty (Saaty & Kearns, 1985) was used to determine the importance of each item. A focus group of 10 people including 2 one-handed disabled due to amputation, 5 hemiplegics who were logical and spoke normally, and 3 medical staff of the rehabilitation center for the disabled who were familiar with the situation of one-handed disabled made the scores of the questionnaire. The one-by-one comparison results of the criteria layer are shown in Table 4, and the one-by-one comparison results of each group for the sub-criteria layers are shown in Table 5. The priority ranking of the 13 needs was derived from the integrated weight value (see Table 6), the integrated weight value of a need is the product of its criteria layer weight and its sub-criteria layer weight. With limited time and cost, prioritizing needs can help designers better understand the high-priority needs of users, reduce cost waste and the risk of innovative product development, and improve the likelihood of successful design outcomes.

The consistency check was conducted to ensure the accuracy of the AHP matrix calculation results. In the criteria layer, CR_X value is 0.009. In the sub-criteria layer, CR_M value is 0.031, CR_O value is 0.004, and CR_A value is 0.004. All of them were less than 0.1, and the consistency check was passed.

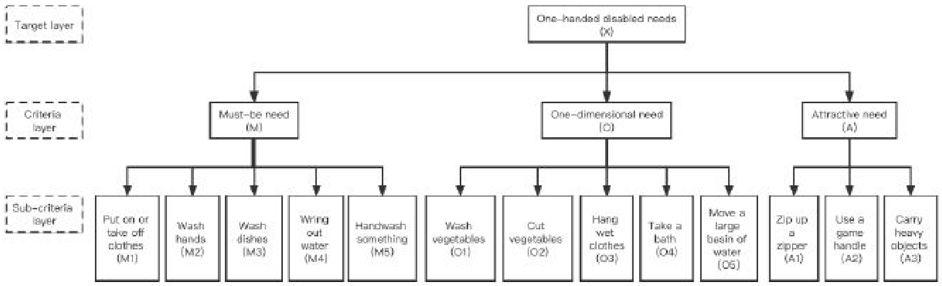

Figure 2: AHP need model of one-handed disabled.

Table 4. Judgment matrix and weight of the criteria layer.

X	M	O	A	Weight value	CR_X
Must-be need	1	2	3	0.539 61	0.009
One-dimensional need	1/2	1	2	0.296 96	
Attractive need	1/3	1/2	1	0.163 42	

Table 5. Judgment matrix and weight of the sub-criteria layer.

M	M1	M2	M3	M4	M5	Weight value	CR_M
Put on or take off clothes	1	1	1	3	1	0.237 72	0.031
Wash hands	1	1	1	1	1/2	0.166 12	
Wash dishes	1	1	1	2	1/2	0.190 83	
Wring out water	1/3	1	1/2	1	1/2	0.116 09	
Handwash something	1	2	2	2	1	0.289 24	
O	**O1**	**O2**	**O3**	**O4**	**O5**	**Weight value**	CR_O
Wash vegetables	1	2	1	1/3	2	0.181 12	0.004
Cut vegetables	1/2	1	1/2	1/4	1	0.098 21	
Hang wet clothes	1	2	1	1/2	2	0.196 42	
Take a bath	3	4	2	1	4	0.426 03	
Move a large basin of water	1/2	1	1/2	1/4	1	0.098 21	
A	**A1**	**A2**	**A3**			**Weight value**	CR_A
Zip up a zipper	1	5	2			0.581 55	0.004
Use a game handle	1/5	1	1/3			0.109 45	
Carry heavy objects	1/2	3	1			0.309	

Table 6. Needs priority ranking.

Needs	Integrated weight value	Ranking
Handwash something	0.156 08	1
Put on or take off clothes	0.128 28	2
Take a bath	0.126 51	3
Wash dishes	0.102 97	4
Zip up a zipper	0.095 04	5
Wash hands	0.089 64	6
Wring out water	0.062 64	7
Hang wet clothes	0.058 33	8
Wash vegetables	0.053 79	9
Carry heavy objects	0.050 5	10
Cut vegetables	0.029 16	11
Move a large basin of water	0.029 16	11
Use a game handle	0.017 89	13

ONE-HANDED DISABLED PRODUCT DESIGN

Due to time constraints, we designed the product with the need to "handwash something" which is the first priority ranking need. Finally, we got the one-handed washboard design and made a physical model, which was tested by one-handed disabled users to show how that it can address the need for one-handed handwash something. This product uses a dense metal material and a non-slip rubber layer design in the contact positions between the one-handed washboard and the sink so that the one-handed washboard can

a b

Figure 3: One-handed washboard usage scenarios.

remain stable on the sink while the user washes a towel or other clothes with one hand (see Figure 3a). And users can squeeze the towel dry with one hand after washing (see Figure 3b) which solves another must-be need “wring out water”.

CONCLUSION

One-handed disabled often place a significant burden on their families because of their life inconveniences. Product design for one-handed disabled can help them face many challenges in life and work independently. The CJM-KANO-AHP user need model is proposed to solve the problems of need collection and need priory ranking in the actual product design for the one-handed disabled. It improves the scientific nature of needs selection, increases the effectiveness of design results, and gives ideas for need analysis of similar product design processes.

Meanwhile, during the random survey process, it was found that one-handed disabled due to hemiplegia accounted for more than 70% of the respondents. Patients with hemiplegia are older, and the facial and lower tongue muscles may have different degrees of motor impairment, which results in slow or even slurred speech and time-consuming communication. It is expected that future survey methods for hemiplegics can be optimized to improve survey efficiency.

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