Design Studies and Intelligence Engineering
L.C. Jain et al. (Eds.)

© 2023 The authors and IOS Press.
This article is published online with Open Access by IOS Press and distributed under the terms of the Creative Commons Attribution Non-Commercial License 4.0 (CC BY-NC 4.0).
doi:10.3233/FAIA220742

Smart Helmet Design Based on KANO Model

Jia Luo [a], Jiaying Zhu [b], Tianli Pan [a], Ziang Ke [a], Yaohui Liao [a], and Lu Lin [a,1]
[a] *Art and Design Institute, Zhejiang Sci-Tech University, Hangzhou, China, 310018*
[b] *School of Software Technology, Zhejiang University, Hangzhou, China, 310058*

Abstract. Based on the Kano model, the personalized requirements of the smart helmet are obtained and analyzed. Focus groups and questionnaires were used to organize and analyze the individual needs of smart helmet users. The questionnaire was designed according to the Kano model, and the collected data results were classified and sorted according to the Kano evaluation table. Determine the desired and attractive needs of users for smart helmets; Based on user satisfaction, intelligent helmet products and corresponding mobile terminals are designed to provide design ideas for product innovation.

Keywords. Smart helmet, The Kano model, Individual needs

1. Introduction

In recent years, with the continuous development of the national economic level, two-wheeled electric vehicles are regarded as one of the best transportation tools due to their high efficiency, environmental protection, convenience and other characteristics. Their ownership continues to grow and their market penetration continues to increase. Therefore, smart helmets have become a popular choice for cyclists. According to the Blue Book on the Green Development of New National Standard Electric Vehicles jointly released by China's Urban Zhiheng Information Technology Institute and the Institute of Transport Science and other institutions, the urban cycling helmet industry is developing in the direction of intelligence, the demand for smart helmets is rising, and the competition is fierce. However, the existing related products cannot meet the needs of cyclists, the product homogeneity is serious, and there is a lack of systematic cycling intelligent terminal. Therefore, the development of a personalized intelligent helmet that meets the needs of consumers has become an urgent problem to be solved in the cycling helmet market.

2. Smart helmet product user positioning

Smart helmet design mainly reflected in its interactive function, the current intelligent riding helmets products on the market development is not perfect, both at home and abroad to meet the most basic security requirements, the features of smart helmet for

[1] Corresponding author: Lu Lin; Postal address: Art and Design Institute, Zhejiang Sci-Tech University, Hangzhou, China, 310018; Email address: vichy0723@126.com

RGB more matrix lamp, bluetooth music, such as telephone answering interactive function is relatively single, homogeneity phenomena and did not have formed a set of complete and unified system of interaction, Ignoring the individual needs of consumers. Effective acquisition and understanding of user requirements and accurate definition of product requirements information in product design can not only shorten the time to market, but also play an important role in taking user satisfaction as the standard of product quality.

2.1. User research on smart helmets

In order to accurately locate the main use of intelligent helmet, through on-the-spot observation method to observe around busy subway traffic intelligent use of helmets (figure 1), the light in the product use the crowd positioning in city groups, mainly consists of urban young white-collar workers, the group of strong ability to accept new things, higher demand for personalized products.

Observation of helmet use - Shentangqiao Metro Station

Time period	Weekdays from 5 to 6 p.m		
After a number of	268 people	Male 61.6% (165 persons)	
		Female 38.4% (103 persons)	
Age distribution	Youth 70.5% (189 persons)	Middle-aged 19.8% (53 people)	Elderly 9.7% (26 persons)
wearing	236 wearing helmets (88%) /32 not wearing helmets (12%)		
Use smart helmet proportions	About 40% male / 50% female (mostly in the young age group)		

Figure 1. Observation of helmet use - Shentangqiao Metro Station.

According to the observation method, 90% of people wear helmets, and some people do not wear helmets when transferring to the subway station, and because the traffic police are off-duty and unsupervised, the number of people who do not wear helmets and wearing helmets accounts for 50%. Men and women also have different preferences for modeling colors. Young women prefer warm colors mainly in red, while young men prefer cold colors mainly in black. In terms of styling, both men and women are streamlined.

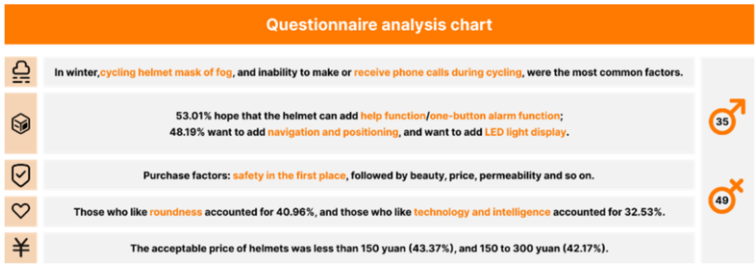

Figure 2. Questionnaire analysis chart.

After that, a preliminary questionnaire analysis was carried out on the user group. A total of 100 questionnaires were sent out and 84 were recovered, and a questionnaire analysis chart was obtained (figure 2). According to the results of the questionnaire, most users belong to our target group, but people have not developed the habit of

wearing helmets and are still in the stage of being forced to do so. However, under the influence of policies, people have to wear helmets, so they have certain needs for comfort, function and aesthetics of helmets. Most of the demand is still from a security perspective.

2.2. Personalized requirement acquisition analysis of smart helmet

Through the above focus groups, user interviews and questionnaires, 10 functional requirements that consumers pay close attention to for smart helmets are summarized, which are (1) voice assistant; (2) solar charging; (3) positioning and navigation; (4) Unexpected help; (5) Internet application access; (6) Air quality testing; (7) LED warning light; (8) adjustable air inlet; (9) Anti-theft and anti-loss; (10) Driving records. (table 1).

Table 1. The user needs

The sorting	Function needs
1	Voice assistant
2	Solar energy charging
3	Navigation and positioning
4	Surprise for help
5	Internet Applications
6	Air quality inspection
7	The LED warning light
8	Adjustable air intake
9	Guard against theft proof lost
10	Driving record

In order to accurately identify the types of user needs, this paper studies product design through KANO model, accurately captures user needs, and uses this method to innovate products and optimize the design process, so as to carry out more targeted innovative design.

3. User requirement analysis based on KANO model

3.1. The KANO model

Kano model is a design model for classifying and prioritizing user needs proposed by Noriaki Kano of Tokyo Institute of Technology in 1984. By classifying different needs of users, Kano model helps designers find the entry point to improve user satisfaction. The nonlinear relationship between product performance and user satisfaction is presented based on the analysis of the influence of user requirements on user satisfaction. As a qualitative analysis model, Kano model is widely used in the fields of Internet user experience, public service and service management. According to the relationship between user satisfaction and basic attributes, the factors affecting satisfaction are divided into five types: Must-be quality (M), one-dimensional quality (O) and attractive quality (M) A), Indifferent quality (I), reverse quality (R). (figure 3)

Basic requirements, also known as essential requirements, refer to the attributes or functions that users believe must exist in a product. When the features are insufficient, user satisfaction will be greatly reduced, but no matter how the attributes or functions are improved, user satisfaction will be within a certain range. Expectation demand

requires that in addition to meeting basic needs, users want to be met, and the satisfaction degree of this demand is positively correlated with user satisfaction. Charm demand, also known as excitement demand, refers to the demand point that can bring surprises to users. The satisfaction can be greatly improved after the demand is realized. If this function is not provided, the satisfaction of users will not be reduced. Indifference requirement means that whether this function is provided or not, user satisfaction will not change; Reverse demand means that the user does not have this demand, which will lead to the decline of user satisfaction. Therefore, according to Kano model, low user satisfaction is due to the fact that the product does not provide basic requirements, expected requirements or reverse requirements. In particular, the lack of basic requirements will cause a sharp decline in user satisfaction. On the contrary, high user satisfaction is due to the basic demand, expectation demand and partial charm demand of the product, and there is no reverse demand at the same time.

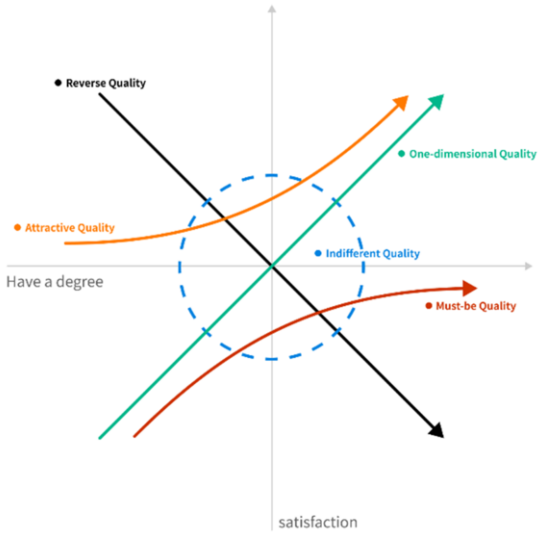

Figure 3. The KANO model.

In the process of analyzing users' personalized needs based on Kano model, it is necessary to obtain users' demand information for product models first, and conduct research on users of related products according to the questionnaire provided by Kano model. Secondly, the collected questionnaire data will be referred to the Kano evaluation table to determine the Kano category to which each respondent thinks the product personalized demand items should belong. Finally, all the functional demand results will be statistically summarized.

For each functional requirement, forward and reverse questions are set from the perspectives of whether it is satisfied or not, so as to understand the user's attitude and demand for some functional features of the product. The answers were set as satisfied, taken for granted, indifferent, acceptable and dissatisfied. The five-point KANO questionnaire was set up and analyzed according to the KANO evaluation table, so as to determine the classification of functional requirements. (table 2)

Table 2. KANO Research and Analysis Evaluation Form(*A - Attractive Quality; M - Must-be Quality; O - One-dimensional Quality; I - Indifferent Quality; R - Reversal Quality; Q - Questionable Quality)

Elements	Satisfaction	Necessary	Unimportance	Endure	Dissatisfaction
Satisfaction	Q	A	A	A	O
Necessary	R	I	I	I	M
Unimportance	R	I	I	I	M
Endure	R	I	I	I	M
Dissatisfaction	R	R	R	R	Q

3.2. KANO questionnaire analysis

The questionnaire was designed based on the personalized needs of users and the requirements of the Kano model. Each survey question was set with two positive and reverse questions according to the needs, and the answers were satisfied, taken for granted, indifferent, acceptable and dissatisfied respectively. Conduct Kano questionnaire test, corresponding to the Kano evaluation table to get the relationship between user requirements and product characteristics. A total of 100 questionnaires were sent out and 90 were recovered, among which 83 were valid. According to Berger's proposal, the importance degree of demand can be obtained by obtaining relative satisfaction S_i and relative dissatisfaction D_i.

$$S_i = \frac{(A_i+O_i)}{(A_i+O_i+M_i+I_i)} \tag{1}$$

$$D_i = 1 * \frac{(A_i+O_i)}{(A_i+O_i+M_i+I_i)} \tag{2}$$

Statistical results obtained after calculation (table 3)

Table 3. The KANO study analyzed the statistical results of the evaluation form

The sorting	Function needs	M	O	A	I	R	S_i	D_i.
1	Voice assistant	6.02%	78.31%	9.64%	6.02%	0%	87.95%	-84.34%
2	Solar energy charging	1.20%	1.20%	6.02%	84.34%	7.23%	7.79%	-2.60%
3	Navigation and positioning	1.20%	1.20%	3.61%	90.36%	3.61%	5%	-2.50%
4	Surprise for help	6.02%	14.46%	75.90%	2.41%	1.20%	91.46%	-20.73%
5	Internet Applications	7.23%	72.29%	3.61%	16.87%	0%	75.90%	-79.52%
6	Air quality inspection	2.41%	2.41%	0%	14.46%	80.72%	12.50%	-25%
7	The LED warning light	83.13%	7.23%	6.02%	3.61%	0%	13.25%	-90.36%
8	Adjustable air intake	80.72%	3.61%	6.02%	9.64%	0%	9.64%	-84.34%
9	Guard against theft proof lost	8.43%	7.23%	73.49%	10.84%	0%	80.72%	-15.66%
10	Driving record	0%	1.20%	1.20%	10.84%	87%	18.18%	-9.09%

In Kano data analysis (figure 4), smart helmet type, a necessary demand mainly concentrated in physical features, such as LED warning lights and adjustable inlet, however, the existing smart helmet products on the market for LED warning light design has been mature, but on the design of the air inlet, did not give users more choice, This is especially reflected in the setting of ventilation range. Therefore, the design of the smart helmet retains the design requirement of LED warning lights while improving the air inlet function.

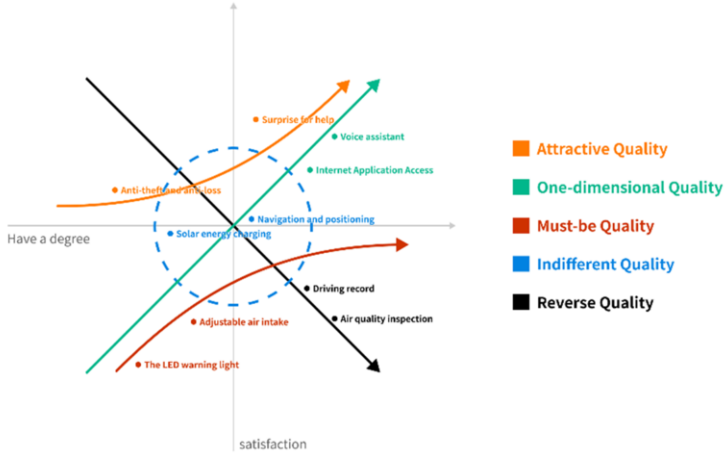

Figure 4. Kano attribute requirement model for smart helmet.

Desired demand is the quality of products that users expect, so it is an important factor that determines the level of user satisfaction. According to the data results, voice assistant and Internet application access requirements belong to the desired requirements that consumers pay attention to, and these two functional requirements are interactive functions, which need to be realized in the process of software development. Among them, voice assistant has the highest expectation, so voice assistant should be prioritized as the key point in the development and design process of smart helmet.

Charismatic needs are generally less than the user's intention. It is found in the survey data that anti-theft, anti-loss and accidental help are charismatic needs. The existence of these two demand functions can greatly improve product satisfaction, so they should be met as much as possible in the design.

4. Smart helmet design

4.1. The design style of the smart helmet is determined

Based on the results of user demand analysis and KANO demand model, relevant modeling intentions were sought and preliminary sketches were drawn (figure 5) to determine the style of the smart helmet. On the one hand, it needs to conform to the public aesthetic, on the other hand, it needs to have the sense of technology of smart helmet. Therefore, we mainly take the modeling language of the taillight as a reference, and try to streamline the light belt on the back side of the helmet. Give users professional, safety and technology, reflect the sense of intelligence and future.

Figure 5. Modeling intention and sketch.

4.2. Smart helmet function planning

Through cooperation with companies of the helmet, to understand the current technology can realize the intelligent function, and considering the company currently has production helmet of technical conditions, the intelligent functions as intelligent speech interactivity and bluetooth module, the Internet based on embedded intelligent chip, these two functions can be iterated perfect by the software, voice through the speakers on both sides of the release. In addition, there is the light intelligent function of LED programmable matrix lamp belt. Through programming, the lamp posts in the lamp belt can change various lighting modes, so as to realize lighting modes such as left turn signal, right turn signal and double jump light (figure 6).

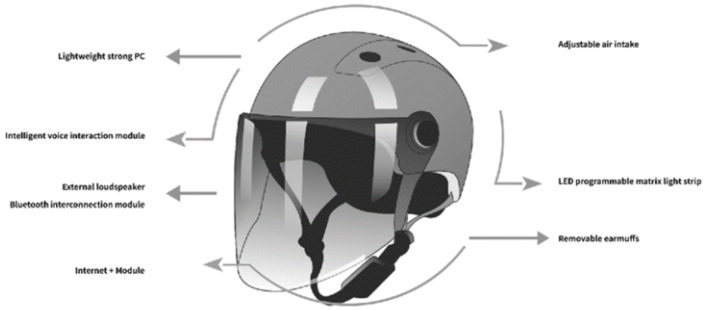

Figure 6. Smart helmet function planning.

4.3. Smart helmet product design

Sketch a smart helmet (figure 7). Above the helmet, an adjustable ventilation channel is adopted, and the ventilation panel is designed by sliding rail. Fully open can maximize the ventilation volume, and closed can optimize the aerodynamic performance. Therefore, when the temperature is high, the user can open the air hole to cool it, when the temperature is low, close the air hole to obtain the best aerodynamic performance. This design breaks the situation of ventilation and ventilation can not be both, users can adjust according to their own needs. In addition, the streamlined light strip extending from the head to the tail is good for showing the flow of light beads on the left and right turn signals.

On the basis of the sketch, the details of the hardware helmet are refined and 3D modeling is carried out (figure 8). First of all, the air inlet made of adjustable structure, when the user feels hot, move the slide to open the air inlet, to achieve ventilation. When it rains, you can close the air inlet. The rear of the helmet is surrounded by light belts and LED light path design, which can be programmed to light up in different forms. The intelligent control is embedded in the front forehead of the helmet, so that users can easily press the button either during or before wearing the helmet.The camber

of the helmet has been adjusted many times to effectively reduce wind resistance while wearing comfort.

Figure 7. Design sketch.

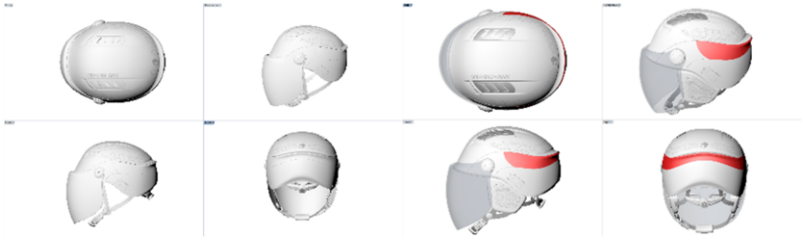

Figure 8. 3D modeling.

After determining the hardware part, we began to make samples with 3D printing (figure 9) to test whether the ergonomic design of the helmet was reasonable. Then we changed the situation of some edge clips during the wearing process and adjusted the shape of the buffer layer. Material and design adapt to product characteristics, the pursuit of simple, beautiful, lightweight, pay attention to performance at the same time there is no lack of safety fashion, improve efficiency.

Figure 9. Proofing of smart helmet model.

4.4. Installation and design of smart helmet components

The internal components of the helmet are shown in figure 10, including main control, main control base, left speaker, left speaker base, right speaker base, right

speaker base, circuit, LED programmable light belt and charging cable. The main control is divided into three parts: microphone, switch, magnetic charging port. When in use, long press the switch to open the helmet. Following the voice prompt, you can connect Bluetooth to the helmet, and then you can use the extension. Of course, the headset can also be voice-activated to turn on the left and right turn signals and warning lights when it is not connected to Bluetooth or the Internet. Due to the good sealing of the components, the helmet supports IPX4 waterproof for daily use, and there is no need to worry about water damage to the components in rainy days

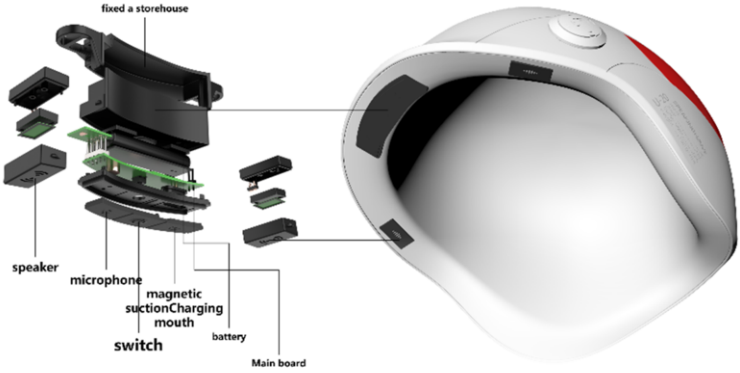

Figure 10. Structure of internal components of the helmet.

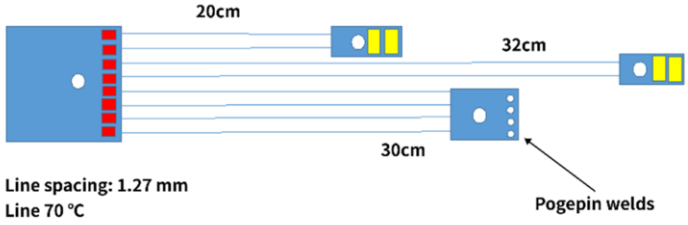

Figure 11. Helmet component circuit.

The main structure of the smart helmet entity includes: helmet mask, adjustable air intake, dynamic light belt module, embedded master control, stereo speakers, ABS housing and other parts. Among them, the dynamic light belt module can not only be used to control the LED warning light cycling and steering, but also freely set the warning light effect and color by connecting the APP, and broadcast the voice through stereo speakers. The embedded master control is used for Internet application access, and the product is controlled through the Internet mobile terminal. It has the functions of recording the cycling track and broadcasting the cycling data, so as to meet the desired needs of users. In addition, the helmet can automatically detect accidental collisions, provide real-time messages to emergency contacts and turn on double jump lights to alert passing vehicles and pedestrians, ensuring the user's life safety. The final product solid model is shown in figure 12.

Figure 12. Smart helmet.

5. Conclusion

Based on the Kano model, this paper conducted a questionnaire survey on 100 urban light riders, obtained objective and accurate user demands for smart helmets, and analyzed and determined the satisfaction degree of light riders with various demands for smart helmets. And through the desired demand function and charm demand function for product design and development, in order to improve product satisfaction, to meet the individual needs of consumers. It provides new design methods and ideas for the cycling helmet market.

References

[1] Kano N, Seraku N, Takahashi F, Tsuji S. Attractive quality and must-be quality. the Japan Society for Quality Control,1984,14(2):39-48.
[2] XU Qian.GB 17761-2018“Electric Bicycle Safety Technical Specification” Interpretation. China Quality and Technical Supervision,2019(3):3.
[3] Zhao Zihao, Meng Gang. Research on innovation and development of smart Cycling helmet. Electronic World, 2021(3):2.
[4] Wang Xinyan, Fan Dawei, Li Jiang. Research on application of KANO model in intelligent flowerpot design. Machinery Design & Manufacture,2017(9):3.
[5] LK Chan, ML Wu. Quality function deployment: A literature review. European Journal of Operational Research,2002,143(3):463-497.
[6] CAI Ningwei, Yu Huiping, Zhang Lihua. Application of participative and non-participative observation in case study. Journal of Management,2015(4):4.
[7] BERGER,C.et al. Kano’s Methods for understanding customer-defined quality. Center for Quality Management Journal,1993,4:3-36.
[8] Zhao Yating, Gu Dongxiao, Zhao Shuping, et al. Research on Functional Requirements of elderly service Robot based on Kano Model. Journal of Hefei University of Technology: Natural Science Edition, 2019,42(10):5.
[9] Kano N,Seraku N,Takahashi F,et al. Attractive quality and must-be quality. Journal of the Japanese Society for Quality Control,1984,14(2):147-156.
[10] Tang Zhongjun, Long Yuling. Research on personalized requirements Acquisition method based on Kano model. Soft Science,2012,26(2):5.