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Requirement Analysis of Smart Kitchen Dietary and Social Service System Based on Older Adults Mental Models

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Abstract. Using kitchen life as an entry point and the theory of mental modelling, we carried out a study on the needs analysis of a smart kitchen diet and social service system, aiming to meet the new needs of the elderly in terms of health and social interaction. Through questionnaires and user interviews, we collected and analyzed the mental data of the elderly and created a mental model of "diet and social interaction" as well as user requirements. The Analytic Hierarchy Process was used to identify the importance of dietary and social needs, covering the four demand directions of diet and nutrition, health management, social interaction, and health awareness. This study highlights the potential of user-centred research methodology in the health and social care of older people and provides useful guidance and insights for the design of future smart kitchens and related products.

Keywords. Mental Modelling, Eating Healthy, Smart Kitchen, Social Service System

1. Introduction

The "14th Five-Year Plan" period is a critical period for China in addressing the challenges of ageing. By 2020, China's elderly population aged 60 and over will reach 264 million, accounting for 18.7 per cent of the total population, and the elderly population is growing rapidly year by year. Society is paying more and more attention to the quality of life of the elderly, and is actively responding to the concept of "active ageing" put forward by the World Health Organisation (WHO), which emphasises the importance of social participation of the elderly. The kitchen, as an important space for daily activities, carries most of the needs of family life, affects the quality of life of the users, and even influences the harmony of family social interaction [1]. The study of intelligent kitchen dietary and social service system can not only meet the dietary needs of the elderly, but also provide a space for social interaction and improve the quality of life of the elderly [2]. From the perspective of mental modelling theory, we think about how to make smart kitchens more age-friendly, so as to improve the life satisfaction and well-being of the elderly, and provide more dietary social service support for the elderly.

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2. Relevant studies

Kitchen plays an important role in human history and is one of the main living spaces of human beings [3]. Starting from the "Frankfurt Kitchen" project in 1926, the concept of modern whole kitchens began to be designed by manufacturers, with more emphasis on user convenience and optimization of the operation process.In the 1990s, with the rapid development of information technology, the prototype of smart kitchens appeared to create multifunctional composite spaces covering parenting, entertaining, and socializing, etc. In 2013, New Zealand kitchen brand Fisher &Paykel organized the "Social Kitchen" design competition, which gave a new meaning to the concept of "social kitchen". In the kitchen scene, we can see the evolution from a material-supportive to a spiritual-emotional kitchen service system.

While about 80% of the elderly in China suffer from chronic diseases, 40% of them suffer from multiple chronic diseases at the same time [4]. Due to the low importance of dietary nutrition among the elderly, it increases the risk of developing multiple diseases in their lives [5]. Smartphone applications can provide appropriate dietary advice. For example, researchers such as Lina Ma developed a dietary program for the elderly, which can achieve effective management of their diets.

3. Acquisition of mental models based on diet and socialisation of older people

3.1. The role of mental models

The theory of mental models was proposed by British psychologist Kenneth Craik in the 1940s[6], who advocated that mental models are the human individual's view of the way the external real world works and are transformed by self-perception to form an internal mental model, which guides human behavioural activities in real life. Mental models can better help us understand users' behaviour and cognition, and deeply explore users' intrinsic needs for products. Zhang Wan yu et al[7] determined the users' cognitive needs through the construction of a mental model and designed a robot service design solution that meets the users' cognition.Abdul Razak F H et al[8] obtained the elderly's expectations for the use of reminder systems through the construction of a mental model for elderly users. The above studies show that the construction of mental models helps to clarify the real needs of users and bring a good experience for them.

3.2. Mindfulness information collection on eating and socialising among older people

The construction of the mental model first needs to fully obtain the user's mental information in the process of using the product, and we conducted a questionnaire survey around the elderly's diet and social interaction in the kitchen. A total of 140 questionnaires were distributed to the elderly in Chengdu city who are over 55 years old, and 120 questionnaires were received. The questionnaires included personal information, Internet habits, diet and health status. The results of the study show that

In terms of social interaction, most of the elderly choose to live with their partners or family members. About 89.67% of the elderly used smartphones to contact friends and relatives, browse news, relax and shop online. 48% of the elderly felt lonely in their

daily lives and had relatively little social interaction, but 66.6% were willing to take part in social activities to satisfy their mental entertainment needs.

In terms of diet and health, 45.83 per cent of the elderly suffer from chronic diseases and are therefore concerned about diet and health. About 64.17 per cent of the elderly have adopted healthy dietary measures. Elderly people usually obtain health advice through television, internet and books. They preferred dietary health products providing features such as healthy recipes, dietary health education and cooking instructions.

When it comes to cooking, older adults usually shop at supermarkets or food markets, with very few ordering online. Older people also pursue the pleasure of cooking, but there is a lack of organised storage of ingredients. Therefore, they hope that the kitchen equipment can provide functions such as ingredient management and partitioned storage of ingredients.

Based on the questionnaire survey, we conducted user interviews with four elderly people. The interviews were conducted in terms of Internet use, smart device use, social habits, interaction, diet and nutrition, and kitchen equipment use, in order to address the behavioural and psychological activities of the elderly in the process of diet and health and social interaction.

3.3. Analysis of the Psychological Needs of Older People for Eating and Socialising

Clustering method is to cluster and classify the information of research and investigation according to the degree of similarity, in the case of different degrees of similarity of the research object, the high degree of similarity will be classified, according to the different degree of similarity to complete the clustering of the research object is the principle of clustering method of classification [9]. Studying the behavioural characteristics of the elderly in the process of diet and social interaction as a demand standard, classifying and clustering the information according to the user's behaviour and the need to use the information in the process of information processing, and then classifying and adjusting and diffusing the information after the clustering is completed, helps us to intuitively understand the behavioural information of the elderly users in the process of diet and nutrition, social activities, etc., and to sort out the relationship between the different demand structures.

3.4. Eating and Social Mental Modelling for Older Users

In the mental model construction stage, we adopted the "affinity diagram" method proposed by Young [10], which is a complete description of the attitudes and perceptions formed by users when using the product. We divided the collected requirements into three parts: ingredient procurement, diet and nutrition, and health knowledge, and then analysed the specific tasks in each part to analyse the problems that older people might encounter in task-heavy tasks, so as to find opportunities for design improvement. Based on user interview data, we learnt that older people usually purchase ingredients from supermarkets or farmers' markets, and sometimes their children assist them in purchasing online. Therefore, when designing the service system, we can consider phone ordering to provide one-click delivery service. In addition, the elderly may encounter problems such as unhygienic operation, not knowing how to cook, and storage of ingredients during the cooking process, so we can provide services such as advice on healthy recipes, partitioning of refrigerator ingredients, and voice-video guidance. Given the limited dietary and nutritional knowledge of the elderly and the high number of patients with

chronic diseases, we can therapeutic recipes, and information. To increase the social aspect of eating and cooking, we can also support collaborative cooking. These analyses build a mental model of eating and social behaviour of elderly users.

Finally, according to the psychological space formed by the classification of the needs and activities of the elderly, the logical relationship between the psychological space is determined and clustered into "diet and nutrition", and finally the psychological model of diet and social interaction is formed, as shown in Figure 1.

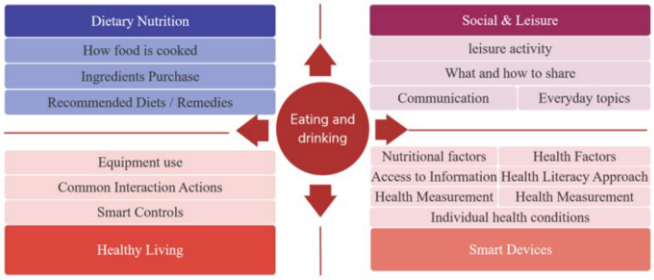

Figure 1. mental model

4. Access to core requirements for smart kitchens for the elderly

4.1. Analytic Hierarchy structural modelling

Analytic Hierarchy Process (AHP) is a quantitative way of thinking about decision-making, by quantitatively analysing the qualitative issues in the study, the objective reality judgments of the relevant experts and users are transformed into quantitative weights, so as to get the importance ranking of the object content [11].

User demand hierarchy is carried out. Based on the user's mind space, the research will determine the relationship between the needs of food and social services, and divided into four subsystems, according to the importance of its different elements to make an evaluation to objectively quantify the needs of food and social services. Setting the target layer A as the importance of dietary and social factors; guideline layers B1, B2 and B3 represent diet and nutrition, health management and social interaction, respectively; programme layer C contains factors C1-C11, and the construction of programme layer factors needs to take into account the operational needs, emotional needs and cognitive abilities of the elderly in addition to the functional needs of the product, and finally establish the demand hierarchy model shown in Figure 2.

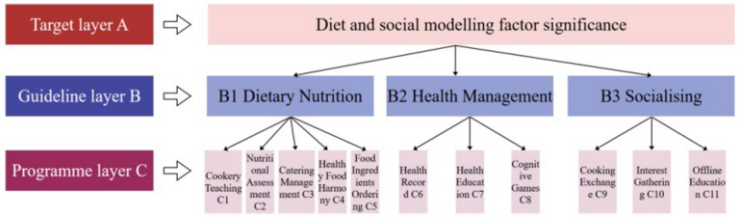

Figure 2. Hierarchical Analytical Structural Model of Dietary and Social Needs.

Constructing a judgement matrix. Experts are invited to compare the importance of the elements in the hierarchical model of dietary and social needs, and relevant data are obtained to construct a comparative judgement matrix. According to the theory of fuzzy

mathematics, the elements in the hierarchical model are rated and quantified by the scale method, and the importance of the elements is assigned by the expert rating method. Experts are invited to assign the weights of C1-C9 to the specific programmes under the guideline layer Bk according to their relative importance, i.e., constructing the pairwise comparison judgement matrix C=(Cij)n×n, and the form of the judgement matrix is shown in Table 1, in which Cij is the importance value of element i and element j relative to the target, and the factor comparison scale is shown in the table 2.

Table 1. Judgement matrix form

B_K	C_1	C_2	C_3	C_4	... ...	C_n
C_1	C_{11}	C_{12}	C_{13}	C_{14}	... ...	C_{1n}
C_2	C_{21}	C_{22}	C_{23}	C_{24}	... ...	C_{2n}
C_3	C_{31}	C_{32}	C_{33}	C_{34}	... ...	C_{3n}
C_4	C_{41}	C_{42}	C_{43}	C_{44}	... ...	C_{4n}
... ...	... ...	... ...	... ...	... ...	... ...	... ...
C_n	C_{n1}	C_{n1}	C_{n1}	C_{n3}	... ...	C_{nn}

Table 2. factor contrast scale

serial number	Importance level	Cij Assignment
1	The two elements ij are equally important	1
2	Element i is slightly more important than element j	3
3	element i is significantly more important than element j	5
4	element i is more important than element j	7
5	element i is definitely more important than element j	9
6	Between the importance levels	3,4,6,8
7	If the ratio of the importance of element i to element a, then the ratio of the importance of element j to element i is 1/a	1/2， 1/3, 1/5 1/7, 1/9

A total of 12 experts and professional caregivers related to research on elderly users were invited to score this study, including three PhDs, seven masters and two undergraduate students. The importance of each factor was discussed and analysed, and the final evaluation results converged.

Calculate the weights and perform consistency test. Calculate the relative weight values, obtain the weight vector W=[wi]1*n, calculate the weight of each element, and obtain the hierarchical single sorting results of A,B1,B2,B3.

$$W_i = \frac{1}{n}\sum_{J-1}^{n}\frac{1}{\sum_{i=1}^{n} a_{ij}}\left(i, j = 1,2,3.....n\right) \tag{1}$$

In order to ensure the consistency of the experts' thinking on the evaluation of various factors in the evaluation process, and to ensure the reasonable validity of the weight calculation, it is necessary to carry out a consistency test on the results after calculating the weight results. The test steps are mainly as follows:

In the first step, Calculate the largest characteristic root of the judgement matrix:

$$\lambda \max = \sum_{i=1}^{n}\frac{\left(AW\right)i}{nWi} \tag{2}$$

In the second step, Calculate the consistency indicator: CI:

$$CI = \frac{\lambda \max - n}{n-1} \tag{3}$$

where λmax is the maximum eigenvalue of the judgement matrix and n is the order of the judgement matrix.

In the third step, Calculate the consistency ratio CR.

$$CR = CI / R \tag{4}$$

Where CI is the judgement matrix consistency index, RI is the random consistency index, and the values of RI for different orders are shown in the table 3.

Table 3. RI values for different orders

1	2	3	4	5	6	7	8	9
0	0	0.58	0.90	1012	1.24	1.32	1.41	1.45

When CR<0.1, the judgement matrix has satisfactory consistency, when it does not meet the standard, it is necessary to re-adjust the judgement matrix scores and test, after the consistency of the calculation of the results are less than 0.1, the judgement matrix are through the consistency test, with validity. The results of hierarchical single sorting and consistency test are shown in Table 4.

Table 4. Hierarchical single-ranking weights and consistency tests.

pairwise comparison matrix	Sorting weight vector	Maximum eigenvalue	CI	Consistency CR
A	W=(0.6144, 0.2684, 0. 1172)	λmax= 4. 10751	0.0358	0.0402
B1	W1=(0. 192, 0.2534, 0. 1342, 0.2748, 0. 1455)	λ max= 5.3211 1	0.0802	0..716

The weights of each level of indicators to the overall target level were further calculated for a composite weight ranking and are shown in Table 5.

Table 5. Table of Weighting Results for Catering and Social Services System.

normative layer			programme level		Combined weights
	Content	Weight 1	Content	Weight 2	
B1	Dietary Nutrition	0.614	Culinary Instruction	0.192	0.118
			Nutritional Assessment	0.2534	0.1557
			Dietary Management	0.1342	0.0828
			Healthy Recipes	0.2748	0.1688
			Ingredients Ordering	0.1455	0.0894
B2	Health Management	0.2684	Health Profile	0.3108	0.0834
			Health Education	0.4934	0.1324
			Cognitive Games	0.1958	0.0525
B3	Socialising	0.1172	Cooking Exchange	0.4934	0.0578
			Interest Gathering	0.3108	0.0364
			Offline Educational Activities	0.1958	0.023

4.2. Functional Requirements for the Dietary and Social Services System for the Elderly

Based on the hierarchical analysis, we derived a hierarchy of needs for food and social functions and analysed the needs for service system functions in the following four areas .First of all, diet and nutrition needs to be analysed for dietary nutrient composition, nutritional intake, analysis of nutritional health data, recommended dietary nutritional recipes, food delivery services, remote assistance for dietary meals, and storage and management of food materials. In terms of health management, it is mainly to record daily drinking water, store and manage medication, learn nutritional and health knowledge, and provide remote assistance. In the aspect of health cognition, it is mainly dietary health counselling, cognitive game training, and multimedia dissemination of health counselling. Finally, in the area of social interaction, there is a social platform for diet and emotional sharing, integrated community activity information, and family communication assistance.

5. Needs analysis of older persons

Based on previous research on the mental models of the elderly and the sorting of their needs using hierarchical analysis we propose the following needs analysis for the Smart Kitchen dietary and social service system:

Dietary and Nutritional Needs: they need the system to provide dietary composition analysis, record nutritional intake and analyse health data. In addition, the system should recommend appropriate dietary recipes. Elderly people may need fresh ingredient delivery service. and need remote assistance from caregivers or children. In addition, the system should provide ingredient storage and management functions to help the elderly better manage their ingredients.

Health Management Requirements: The system should record data about the user's body and diet to create a personal dietary health profile. This helps in tracking health conditions. The system can also record the user's daily water intake and provide storage and management of related items. In addition, the system needs to provide health counselling to help the elderly better understand diet and health.

Social Interaction Needs: The elderly want the system to provide a platform for social interaction and emotional sharing. They are eager to share their dietary experiences with other seniors, as well as socialise with people through the system. The system should also integrate information on community activities to facilitate social interaction.

Health Cognitive Needs: Older adults need the system to provide diet and health counselling services to answer their questions about health and diet. Cognitive training games should also be developed. In addition, health awareness among older adults can be raised by providing information on chronic disease treatment and related videos.

6. Conclusion

Against the backdrop of an ageing society, the quality of life and spiritual needs of the elderly are increasing, and the daily dietary and nutritional needs of the elderly are also receiving much attention. The daily dietary nutrition, physical health and socialisation needs of the elderly are also of great concern. Behind the demand analysis of smart kitchen service system based on mindfulness model is to meet the unique dietary and social needs of older adults and to serve their physical health and mental health. This study aims to gain a deeper understanding of the lifestyles of older adults thereby constructing a mental model. By weighting the needs of the elderly, it helps us to better analyse and summarise their demand tendencies. The smart kitchen based on diet and socialisation takes on the function of diet and health while promoting communication between the elderly and their families through gathering and entertainment, interactive communication, etc., forming a living space that meets the diet and socialisation needs of the elderly and creates an atmosphere of family communication. This research helps to address the challenges of an ageing society, promotes technological innovation and extends mental modelling approaches to other fields.

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