A human-machine interaction Solution for household medical furniture design

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Abstract. In the current situation of covid-19 pandemic, the supply and demand relationship of medical resources in various hospitals is unstable. However, people's needs for understanding their health status are increasing. The purpose of this project is to assist telemedicine so that people can check their health at home. So, we proposed a civilian medical furniture solution. In the solution, we took the chair design as an example. First, we found out the user's needs and pain points via observation and interview. Based on this, we analyzed the characteristics of chair design and developed a prototype using a flexible contact sensor technology. In a follow-up evaluation experiment, we also added the details of the product according to ergonomic design principles of sitting posture. Moreover, after obtaining the heath data of users, we improved the product quality by visualizing the data. Finally, we tested the interactive effects of data visualization and then received positive feedback from users. The results of this project could help the design and development of civilian medical furniture.

Keywords: Health, Medical furniture, Flexible bionic tactile sensing technology, Human-machine interaction, Visualization.

1 Introduction

The advancement of China's medical standards has raised people's health awareness. Therefore, a number of people are undergoing regular physical examinations and this trend is increasing day by day [1]. However, people in some areas where medical facilities are limited, patients have to experience long waiting time in hospitals for outpatient consultations, physical examinations, or re-examinations [2]. Telemedicine and new technology can provide new methods to address the excessive burden to hospitals, especially when the medical conditions are not very critical. One technology, the flexible bionic tactile sensing technology has developed rapidly [3] and this technology has been applied in the medical robot industry as well as in smart homes [4, 5].

Flexible bionic tactile sensing technology has the characteristics of high flexibility, high sensitivity, and wireless signal transmission [3]. It can be easily integrated with existing medical robots [4]. This technology can also be combined with smart homes and smart car applications [5]. Also, the product can detect the movement of every muscle and tendon of a person through the use of bionic tactile sensing technology, thereby analyzing the person's posture [3]. Therefore, this technology also has broad application prospects in gesture recognition and motion analysis in functional products [4].

For medical examinations in the home environment, the characteristics of flexible technology just make the solution of telemedicine possible [10]. The current era is a smart technology era in which consumers widely use Internet services and Internet enabled products which cater for different user experience [7]. In the smart home environment, compared with traditional electronic sensors, users drag countless wired, hard, and non-fitting medical monitoring equipment to perform various tasks. In this proposed design, users are more inclined to use products that use flexible bionic tactile sensing technology [6, 8]. Therefore, this research uses flexible sensor technology and combines aesthetics and interactive habits to design household medical furniture. *Leisure seat*, a proposed conceptual design, can be used in future smart home environment to initially detect the health problems of each member of the family by initial screening for early diseases at home.

People have considered the design and development of telemedicine from different directions. Some have put a "warm and kind" material shell on the cold medical equipment in the CMF (i.e., Color-Material-Finishing) design to make it commercialized and civilian. Others have removed redundant functions in equipment and only retain functions that have low detection accuracy but can detect important physiological data. Consider medical furniture as an example. The current medical furniture has the most basic functions, but the auxiliary functions are not perfect. For example, hospital beds, infusion chairs, etc. can provide the most basic functions, but they do not significantly help doctors to treat and improve the efficiency of medical staff. In densely populated hospitals, the available space per person is small, and it is particularly important to save space on furniture or to provide multiple functional services on a piece of furniture.

Take Apple's smartwatch as an example. In addition to heart rate testing, Apple Watch also pays attention to people’s breathing, sound, healthy drinking, and so on. The latest sixth-generation of smartwatch can measure blood oxygen levels through innovative sensors and apps; it can also monitor the health of the heart; it can also show various fitness data at a glance on an optimized all-weather retina screen. This can well meet the needs of users to understand their health in general. However, because of the area to be measured, the method of measurement and the type of data measured is limited. There is still much room for improvement in the accuracy of the health data [17, 18].

In the furniture field, people have more contact area and spend more time in the chair. So, this study considered the design of the chair. Starting from the interaction mode between the chair and the person, this study explores the design of contact points and interaction of the product. In this research, we have proposed a conceptual design of home medical furniture that can be used for medical testing and can be used as conventional furniture, while also conforming to ergonomics and human-computer interaction. The purpose is not only to better detect physiological data but also to better integrate it into the home environment. First of all, through observation and interviews, in ensuring the basic functions of the furniture, we found out the problems related to ergonomics in furniture and looked for the contact points between the flexible sensor and the furniture that may interact with the human body. Next, based on the above findings and analysis, we formulated the design requirements and propose design concepts. Feedback from users was obtained using a simulation test.

This paper introduces the application of flexible bionic tactile sensing technology and ergonomic principles in the product design process of home medical chairs in detail.

2 User research

User research consists of two parts: (A) Observe the interaction nodes between people and the chair during the whole process of using the chair by people of different ages, and explore the design touchpoints (i.e. contact points) of the product; (B) Conduct structured interviews on the medical testing habits and personal opinions of users and family members, which will not only prove the insightful design concept of part (A) but also benefit developing novel design concepts.

2.1 Observation

We observed the dynamic process of people in the use of the chair and analyzed the design node diagram of the chair. The armrest is in close contact with the human hand and is an important source of human physiological data; the surface of the chair is the stress point and the main detection part of the flexible pressure sensor; the backrest must fit the curve of the human back to relieve pressure on the lumbar spine and relax the body; the legs of the chair are the supporting part of the entire product, and the strength and performance of its structure need to be considered (see Fig. 1).

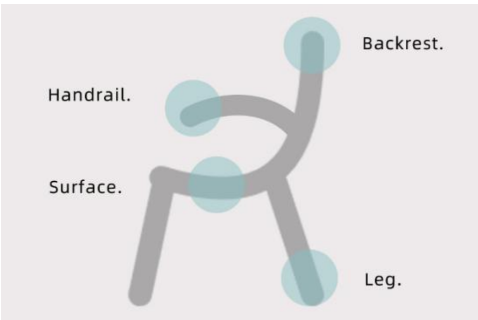

Fig. 1. The design node diagram of the chair.

The results of Bleda et al.’s study show that direct contact between the flexible sensor and the skin will result in more accurate human physiological data [10]. If the direct contact part is the user's palm, wrist and forearm area, then the quality of the human physiological data will be higher [10]. Therefore, we arrange the position of the sensor in the position of the armrest to improve the accuracy.

The product experience process was shown in Figure 2. The first step is to sit on a telemedicine testing chair or product; the second step is to identify the identity and start the test; the third step is to generate a health report and send it to the remote family doctor; the fourth step is to discuss and summarize a more comprehensive health report by the remote doctors in each department; the fifth step, the attending doctor feeds back the health report and gives health advice (see Fig. 2).

Fig. 2. Product experience process.

2.2 Interview

Interviews with users of different ages and their families (41 different families, 153 people in total) were conducted to understand what types of health testing products they have used. We asked them about their experience and questions about using the product. The following are some common questions collected. First of all, they reported that there are too many types of testing equipment. For example, measuring blood pressure, blood sugar, and body fat require three different instruments. And the interface and product usability are also very different. Some equipment needs to be tied to the arm; for some equipment needs to stand, and others are inconvenient in daily use. Even the use of some equipment does not conform to ergonomic. Secondly, the data can be viewed, but requires manually or separately recording. This creates confusion and is not effective in providing comprehensive understanding of their health status and trends. Finally, they hope that the testing equipment can be easy to use, does not take up more space, and be easy to carry.

3 Design process and program output

The user research results provide an effective reference for the design concept and the program output. It was found that product integration, ergonomics, and data visualization are the most prominent problems that users expect to solve. Therefore, we determined the design principles and designed a new solution. To ensure the basic functions of the furniture, the flexible sensor is etched on the contact point where the furniture and the human body may interact. The advantage of this is that it does not affect the normal use of the furniture, and can accurately detect various physiological data of the user during contact with the human body. Compared with traditional medical furniture in the hospital, it can better integrate into the home environment. And there is the choice of shape, material, and structure for different personality and individual styles. In addition, it does not occupy a lot of space in terms of volume.

First of all, the technical analysis is as follows. The flexible sensors developed at present include flexible gas sensors, flexible temperature sensors, flexible humidity sensors, flexible pressure sensors, and flexible strain sensors (also called flexible bionic tactile sensing technology, which is the main electronic skin Original), a flexible magnetic impedance sensor, and flexible thermal flow sensor. However, due to the limitations of technology, detection methods, and transmission power problems, an analysis of its ability when applied to medical health detection is shown in Table 1, 2 and 3). There is a need to design a human-computer interaction model that matches these flexible sensors.

Table 1. Home self-test equipment.

Equipment category	**Device**	**Features**	**Equipment iteration**
Home self-test equipment	Blood Pressure Monitor	It can measure the blood pressure data indirectly by Oscillographic method	Flexible pressure sensor
	Blood glucose meter	It can measure and evaluate human blood glucose levels.	Flexible pressure sensor
	Digital Thermometer	It can use semiconductor temperature sensing resistors to measure body temperature data.	Flexible pressure sensor
	Ear thermometer	It can use the infrared spectrum emitted by the eardrum to measure body temperature.	
	Pedometer	It can calculate calories or calorie consumption by counting steps, distance, speed, time and other data.	
	Human health scale	It can check human health (weight, fat).	Flexible strain sensor
	Smart fat	It can measure body weight, fat, water,	Flexible

	scale	muscle weight, etc.	strain sensor
	Body composition measuring instrument	Body composition measurement: body weight, obesity judgment, body age, basal metabolism, muscle mass, estimated bone mass, body fat rate, visceral fat level, exercise mode, etc., which can be accurate to the various health indexes of the hands and feet.	Flexible strain sensor

Table 2. Medical smart wearable equipment.

Equipment category	**Device**	**Features**	**Equipment iteration**
Medical smart wearable equipment	Smart cervical ring	It can monitor cervical spine and body state, including neck posture, posture correction, sedentary reminder.	Host system
	Smart monitor	It is easy to carry, can monitor the heart health at any time, accurate diagnosis of heart disease.	Flexible strain sensor
	Sensor smart suit	It can monitor our physical condition, exercise status, and metabolism status at all times, and make our dynamic and static life and body characteristics digitized.	
	Smart sports shoes	It can measure the user's running distance and other information. It can not only measure the route, but also measure the heart rate while running.	
	Intelligent blood pressure detection	Using a variety of communication methods (Bluetooth, USB cable, GPRS, WiFi, etc.), the measurement data of the electronic sphygmomanometer is uploaded to the cloud through intelligent processing to realize real-time or automatic timing measurement and record the user's blood pressure value, and intelligently analyze blood pressure changes.	Flexible pressure sensor
	Smart heart rate detection	It can record real-time data such as exercise, sleep, some food and others in daily life, and synchronize these data with mobile phones, tablets, iPod touch, and play a role in guiding healthy life through	Flexible strain sensor

	data.	
Intelligent ECG monitoring	It can synchronously save and record the user's ECG data in real-time, health trend analysis, and the cumulative data can be formed into a columnar trend analysis chart, which is convenient for users to grasp the law and trend of heart health.	Flexible strain sensor
Intelligent three-high detection	It can monitor the user's blood pressure, blood sugar, blood lipids and other data in real-time, extract and visualize abnormal data.	Flexible strain sensor
Oximeter	It can get the data of blood oxygen saturation and pulse by detecting fingers.	Flexible strain sensor
Smart wearable chip	It is divided into four parts: including two ECG engines, a biometric recognition engine, and a heart rate heart disease recognition engine. Among them, the biometric engine can determine whether the tester is the owner himself or not according to the heart condition.	Flexible strain sensor
Cardiovascular tester	It can obtain a set of 35 cardiovascular function parameters and 64 expert-assisted diagnosis information reflecting heart function, vascular status, blood status and microcirculation function.	Flexible strain sensor
Sweat detection	Instead of blood testing, it can monitor the body's electrolyte imbalance, lactic acid index, sweat glucose level, dehydration and calorie burn value.	Flexible strain sensor
Mobility aids	It can accurately process more complex and digital signals to improve the quality of life of the disabled and the elderly.	
Intelligent diagnostic instrument	It can analyze body data such as body composition, body shape, body function, etc., comprehensively evaluate the health status and exercise ability of the user.	Flexible strain sensor
Smart eye tracker	It can record the eye movement characteristics of people when processing visual information, and study the user's mental health by examining eye movements.	Flexible strain sensor
Dynamic health monitor	It can collect the blood oxygen saturation and pulse volume of the user during the activity, and then analyze the blood oxygen saturation and pulse volume to obtain	Flexible strain sensor

		the user's current health status.	

Table 3. Home health equipment.

Equipment category	Device	Features	Equipment iteration
Home health equipment	Massage chair	It can use mechanical rolling force and mechanical force squeeze to perform the massage. Regular massage can dredge the meridians and promote blood circulation.	
	Eye massager	It can relieve visual fatigue, prevent myopia and amblyopia, can clear the meridians, improve blood microcirculation in the eyes, promote metabolism, relieve eye fatigue, and restore ciliary muscle elasticity.	
	Physiotherapy bed	It can activate the activity of biological macromolecules, promote and improve blood circulation, enhance metabolism, improve human immune function, have anti-inflammatory and swelling effects, and relieve pain.	Direct use

Secondly, ergonomic considerations focus on the seat size and the inclination angle. Because it needs to provide a comfortable experience, and at the same time prevent the users from increasing fatigue by prolonged and constant posture. Also, there is a need to avoid the user's long-term bowing operation, then increase the pressure on the cervical spine. We refer to the ergonomic size of the driving seat of a car with similar needs [12, 13].

Also, the *sinking amount of the chair* is a key consideration [14, 15], where the *sinking amount of the chair* refers to the extent to which the chair is downward when a person is sitting in it. It can make the seat surface and the backrest of a single-curved fit the user's back curve when used. Then make the curvature of the spine in a natural state. The design can avoid abnormal pressure distribution in the intervertebral disc which can damage the spine and increase the fatigue of the user.

Finally, based on the results of the previous product experience process analysis, we set up the following specific usage processes and functional principles: When the user sits on this chair, the flexible temperature, pressure, and strain sensors in the cushion start to operate. Then it can detect the user's metabolic status, body temperature, and other physiological conditions in real-time. The user holds the armrest of the chair with both hands and then triggers the flexible bionic tactile sensor etched on the armrest. It can extract the user's biometric information and various indicators that can reflect the user's physical health from the user's palm prints and sweat. If the neck is leaning on the magnetic cervical spine pillow, it can also detect the information of user's cervical spine and physical condition, and then transmit it to the intelligent processor of the chair.

Using software and hardware with Artificial Intelligent algorithms (AI brain) the data is stored and also compared with previous files and standard human health indicators. The complex human health information is visually display on a flexible screen. Users only need to have basic physiological knowledge to understand their health intuitively. If any data is not within standard, the system can give corresponding suggestions based on the data. These may include possible disease, severity and potential consequences.

The user can also open the telemedicine system and directly communicate with doctors online in the cloud through the high-definition camera and eye tracker in front of the flexible screen display. Alternatively, the physiotherapy pad embedded in the cushion can be used to reduce inflammation and swelling, relieve pain, promote the blood circulation, enhance metabolism, and improve human immunity.

Based on the previously summarized design principles, and combining it with the use process and functional principles, we propose the following conceptual design (see Fig. 3, 4 and 5).

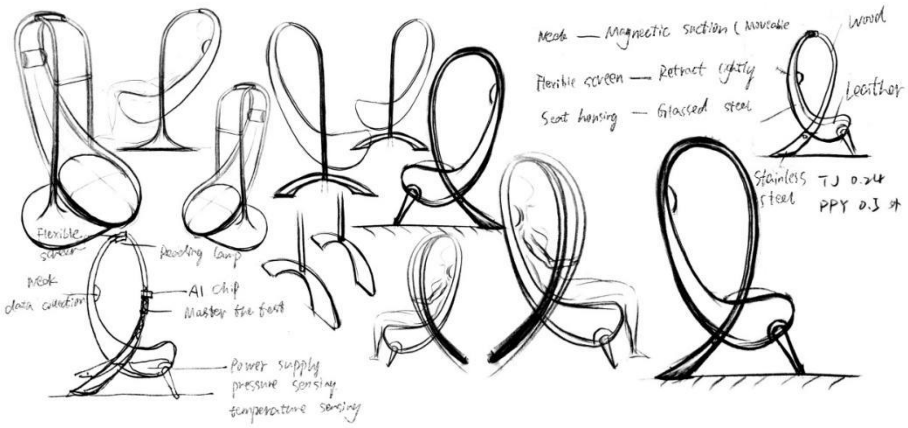

Fig. 3. Concept sketch of chair design.

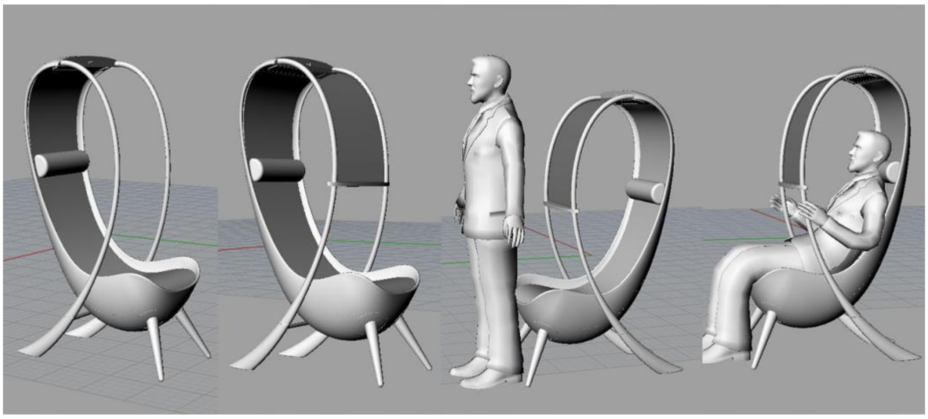

Fig. 4. Computer model diagram.

Fig. 5. 3D printing model diagram.

4 Performance Analysis

The final rendering of the conceptual model is shown in Figure 6.

Fig. 6. Chair scene diagram.

In addition to its health detection function, it is also a leisure health chair. And it is mainly used in the home environment, such as living rooms, bedrooms, balconies, courtyards and other environments. Due to the unique shape and avant-garde CMF design, it can be integrated into various modern home styles.

Besides, it can also be placed in public places such as the hospital lobby, waiting room, waiting room for relatives, etc. The various soft and sensitive sensors can also be applied to popular VR (Virtual Reality) games. This is an absolutely novel entertainment revolution for us, which not only satisfies the entertainment needs of users, but also extricates users from the bad habit of playing with mobile phones with bowing their heads.

From an ergonomic point of view, referring to the size and the inclination design of the car seat, the overall size of the chair we set is 1065*600*1780mm, seat width is 600mm, the seat depth is 500mm, and the seat height is 450mm. The neck pillow is magnetic and can be moved according to user needs. The inclination angle between the seat cushion and the backrest is 95 degrees (see Fig. 7).

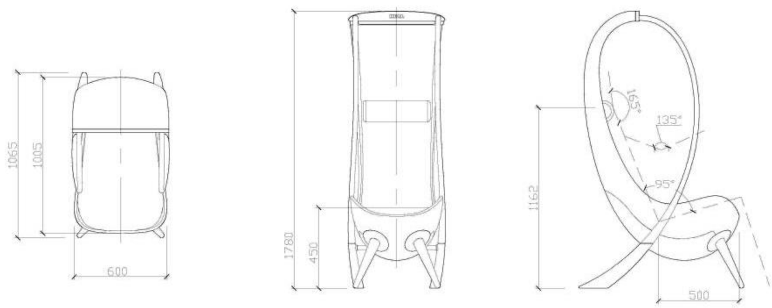

Fig. 7. Seat size and inclination design.

To improve the comfort of the seat, we designed a high-elastic foam with a cushion of 50mm (i.e., sinking amount) on the seat surface. And based on the previous analysis of the sitting posture, a medium-density sponge with a cushion of 40mm (i.e., sinking amount) for the shoulders and thighs was set up. The rest is a 10mm low-density sponge (see Fig. 8).

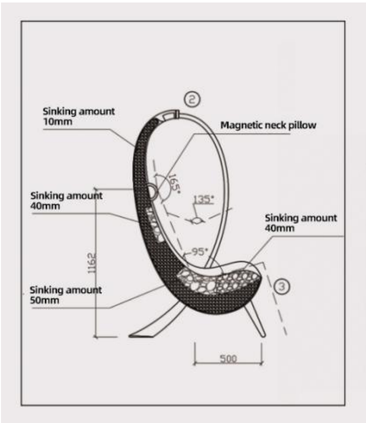

Fig. 8. Seat sponge design.

The evaluation of the innovation points of this design has the following points: First, user needs, people have the awareness of regular physical examinations, people want to know their health conditions, and they require functionally integrated household products; second, technical feasibility, flexible sensing technology is becoming more and more mature, intelligent chip information processing technology is powerful, and the etching technology of flexible sensing sheet is progressing; third, business continuity, the state's support and attention to the medical and health field, users need physical examination services without leaving home and a new software and hardware interactive experience.

Finally, in terms of data visualization, the interface design allows users who do not understand medical knowledge to understand their health through visual design [16]. The functional interface of this system is divided into five sections as shown in the menu bar: telemedicine, member files, health reports, film and television programs, and entertainment games. This article focuses on the visual design of the health report.

In the health report, there are five modules: data list, human body three-dimensional grid display, severe abnormality index, controllable abnormality index, and risk assessment. Among them, the data list mainly displays all the health test data of the identified user, except for basic height, weight and other information. Because standard control data is set in each test item, users can intuitively see the deviation of each health data from the standard data. In the three-dimensional grid display frame of the human body in the middle, the parts with abnormal data will be marked in red. Because the display is a virtual three-dimensional human body model, users can freely zoom in or zoom out the parts marked in red and share screenshots on their smart devices to facilitate communication with doctors.

The first column on the right is the serious abnormality index display column, which shows the prevalence index of large diseases, such as the early preliminary screening of tumors and cancers. The second column on the right is the controllable abnormality index display column, which displays the values of the more abnormal items in the data list on the left, for later reference when consulting a doctor. The third column on the right displays field of risk assessment, showing that the probability of suffering from various diseases calculated based on the controllable index (see Fig. 9).

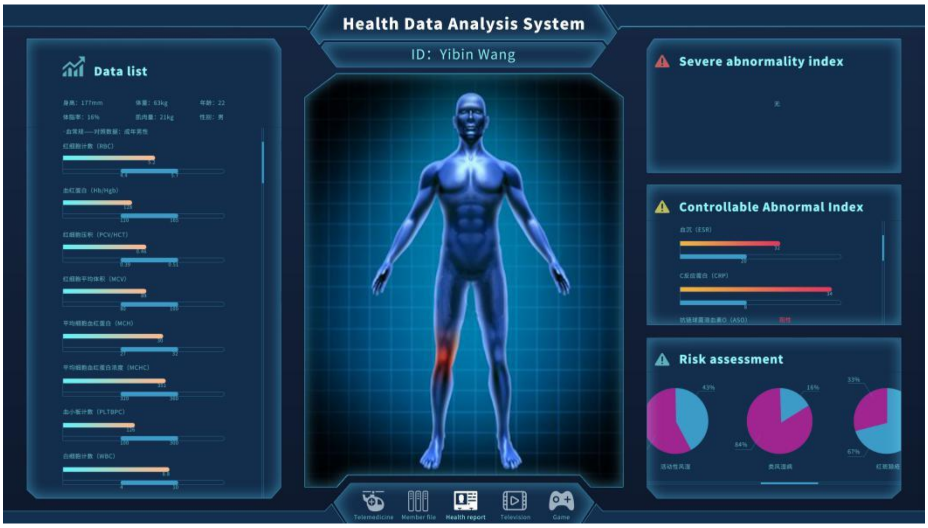

Fig. 9. Health report homepage interface design.

The main interface of telemedicine matches with cloud platforms such as Alibaba Health and Xiliudata and lists the product profiles of clients such as Doctor Yun, Dingxiang Doctor, and Good Doctor Online for users to choose from (see Fig. 10).

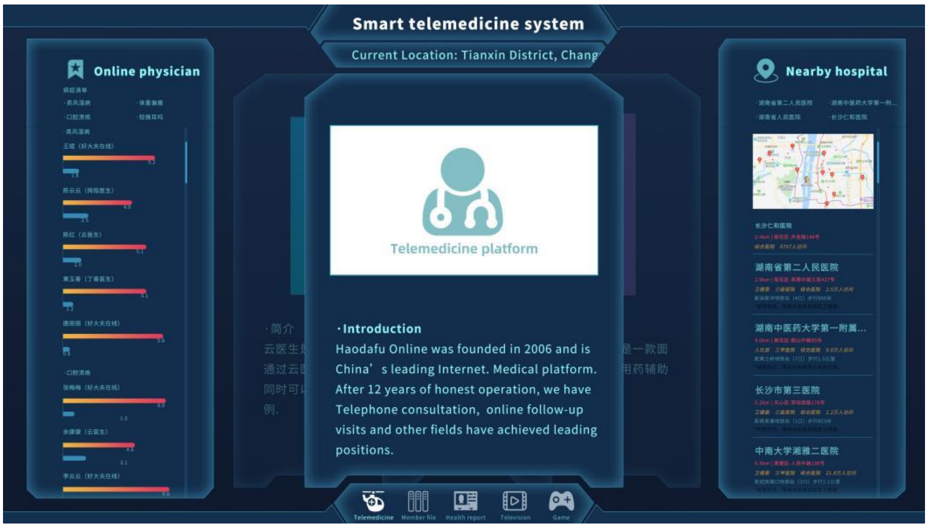

Fig. 10. Telemedicine client interface design.

The member files mainly display information data files of family members. There is a suggestion column on the left, which lists the matters that each family should pay attention to in daily life and recent physical conditions. The interface design of film and television programs and entertainment games is consistent with the interface design of today's major online video platforms.

To test the effect after visualization, we conduct a test on several volunteers via the popular projection technology. Based on the volunteers' feedback, knowledge of physical health, simple disease prediction, and even establish a simple family medical file, is a good realization. Through the chair we designed, the perfect combination of home and medical care can be realized and applied to daily life. This can alleviate the current ubiquitous medical difficulties and expensive medical problems, and lead people to a healthier and smarter medical life.

5 Conclusion

Smart furniture design solves the storage problem of multiple home medical equipment with a single function. Users do not need to leave home to obtain health reports and can conduct preliminary screening for early diseases to prevent the arrival of diseases in advance. There is no need to waste time go to hospital to queue up for routine physical examination.

Although the solution of this research has a certain accuracy limitation when compared with the medical equipment of hospitals. Improvement of the system requires subsequent iterative optimization of technology and several prototype developments. On the level of solving telemedicine problems, it has certain feasibility and potential usefulness. Compared with the smartwatch, although the contact time between furniture and people is not as long as the contact time with the watch [17, 18], it has a wider measurement area, can have accurate sensors, and richer measurement methods to meet the needs of telemedicine data.

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