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EAR-NURSING: An Interactive System Design for Ear Canal Health Care

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Abstract. Ear canal care is one of the common life behaviors in people's lives. According to ENT physicians, inappropriate ear canal care practices may lead to several diseases such as fungal otitis externa, secretory otitis media, suppurative otitis media, and external ear canal eczema, all of which are the types of diseases visible in the ear endoscope. In this paper, the research team designed an interactive system, EAR-NURSING, based on a thorough study of existing ear canal care approaches, which can support users to visualize and integrate ear canal care in scenarios of ear canal discomfort, and can scientifically care for ear canal health utilizing temperature regulation and multimodal sensors, while transmitting and recording real-time data on ear canal health. EAR-NURSING is a head-mounted ear protector (smart hardware) with multimodal sensors and a professional endoscope on the structure, using component sterilization, 360-degree rotation, adsorption, caressing, temperature control, music therapy and data collection and analysis technologies, and matching a smartphone app to achieve the goal of safe, comfortable and healthy ear canal care, thus predicting and examining the health index and lesion possibility in the ear canal, tracking it well with data and recording it. We also applied qualitative, quantitative, and hands-on design methods to conduct a preliminary user study of EAR-NURSING, which showed that most of the users had high perceived interest and willingness to use EAR-NURSING and were confident in the health care of their ear canal.

Keywords. Ear-nursing, Interactive system, Ear canal nursing, Digital design, Design study

1. Introduction

There are always different health risks in people's daily life. From the most subtle daily point of view, the incorrect way of ear care will also bring hidden diseases such as fungal otitis externa, secretory otitis media, suppurative otitis media, and eczema of the external auditory canal. Because way people clean the ear canal is applied: ear-digging tools, cotton swabs, little fingers, visual ear-digging sticks, and otolaryngology professional doctors. Except that otolaryngologists are the most reasonable way, all other ways may lead to bacterial infection of the external auditory canal. With the rapid

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development of science and technology, our research team designed EAR-NURSING interactive system, an innovative ear canal healthcare system combining hardware and software. The hardware system is a wearable ear protector that has considered ergonomics. It is also easy to clean. It is internally equipped with a rotating and adsorption drive device and embedded with a multimodal microsensor. At the same time, the probe rotating into the ear is equipped with a micro-professional endoscope. The software system is an application app with multiple interface function designs (home page, learning video, rotation, adsorption, stroking, temperature control, music therapy, data acquisition, analysis, etc.). In the process of using the EAR-NURSING interactive system, the hardware system and software system can be connected through Bluetooth or Wi-Fi. The user can control the hardware system through the application app to start a healthy and comfortable journey of ear canal cleaning and enjoyment. The system will record, collect and analyze ear canal health data in real-time through the application of endoscopic sensing technology. In the early stage of designing and building the EAR-NURSING interactive system, we used the method of a questionnaire survey to summarize the core issues that most users are most concerned about. We also invited experts from the Department of Otolaryngology, senior engineers in the AI field, and design professors to have a series of in-depth exchanges and discussions, and created an interactive system design prototype. To get users' feedback on the user experience of the EAR-NURSING interactive system, we carefully selected relevant users with strong representation and conducted preliminary user research. The results showed that experts and users felt more recognized in the process of participating in the front-end design and user experience, and their attention to the health cognition of ear canal nursing and innovative nursing methods has been greatly improved.

The main innovations of the EAR-NURSING interactive system are as follows:

- an interactive system is designed and built, including a hardware module of a head-worn ear protector and an application app to help users get a comfortable experience and real-time data feedback during ear canal nursing;
- Through video learning, further improve the cognition of ear canal health science popularization and how to correctly use EAR-NURSING interactive system to prevent and promote the comprehensive nursing of the ear canal and even brain;
- To demonstrate the effectiveness of the EAR-NURSING interactive system, we let users participate in and discuss the whole process of pre-design and post design user experience testing. We also invited experts from the Department of Otolaryngology, senior engineers in the field of AI, and design professors to jointly study and obtain positive and effective feedback.

2. Related work

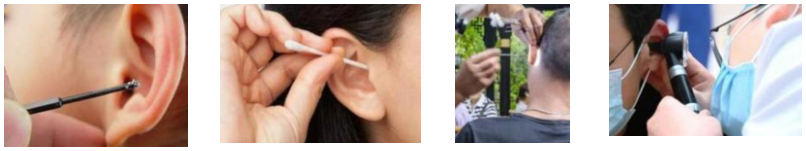
After collecting, fieldwork, and data collation, the research team can be summarized into two major areas: the study of ear canal health care knowledge and the design of a human-computer interaction system for ear canal health care.

2.1. Research field of ear canal health nursing knowledge

According to the doctors in the Department of Otorhinolaryngology, inappropriate ear canal care may lead to fungal otitis externa, secretory otitis media, suppurative otitis media, eczema of the external auditory canal, and other diseases, which are all visible under the ear endoscope and are caused by external factors. After sorting out relevant data at home and abroad, it is found that Prasad R J, et al.'s research is specially used to study and compare the changes in ear size, especially height, and width, of medical and nursing students in Nepal [1]. Harkin H. proposed that the ears provide the important functions of hearing and balance. Ear problems can be debilitating for patients and may also be associated with other health conditions[2]. Perry E T, et al.found that The external ear canal is a highly distinctive anatomical site, both geometrically and histologically. It is a small restricted area, and yet commonly it presents dermatologic problems[3]. Jasim H A studied the types of bacteria found in the ears, mouth, and nose[4]. Meyer C, et al.proposed that Nursing interventions should focus on cerumen management to reduce hearing impairment and allow for the use of hearing devices[5]. IBRAHIM M K, et al.pointed out that Awareness and knowledge of nursing care in ear, nose, and throat disorders[6]. Hamza Mukhtar D, et al.confirmed that roat infections are more common than those of the ear and nose moreover the prevalence of ENT issues is at a higher rate that is around 54%. There are four main reasons which often cause ENT problems[7]. Dosemane D, et al.proposed that the study objective was to ascertain the level of knowledge of the community regarding ear care, to find out whether some of the common conditions affecting hearing are known, and to find out the common practices involved in maintaining ear hygiene[8].

2.2. Design of ear canal nursing human-computer interaction system

The human-computer interaction system for ear canal nursing in domestic and foreign research is based on the visual interaction stage of ear canal cerumen cleaning, and further research on the interaction system is slightly insufficient. At present, the main ways of ear canal nursing are: Pisha L, et al.developed a wearable and extensible open-source platform for hearing nursing research[9]. Uzun L studied the antimicrobial activity of garlic derivatives on common causative microorganisms of the external ear canal and chronic middle ear infections[10]. Klyn N A M, et al.designed CEDRA–a tool to help consumers assess the risk for ear disease[11]. Viscaino M et al.studied computer-aided diagnosis of external and middle ear conditions: A machine learning approach[12]. Abdelkareem Bedri, et al.described the design and the implementation of the Outer Ear Interface (OEI) which utilizes a set of infrared proximity sensors to measure the deformation in the ear canal caused by the lower jaw movement[13]. Viscaino M, et al.developed that computer-Aided Ear Diagnosis System Based on CNN-LSTM Hybrid Learning Framework for Video Otoscopy Examination[14]. Morris E, et al.developed and validated a new ear simulator for teaching pneumatic otoscopes [15]. Taniguchi K, et al.developed a point-of-care ear sensor for respiratory rate measurement[16]. Pedersen J E N. proposed that digital otoscopy with AI diagnostic support: makes a diagnosis of ear disease more accessible[17]. Athavipach C, et al.discussed a preliminary study to develop a wearable device that is a low-cost, single channel, dry contact, in-ear EEG which is suitable for non-intrusive monitoring[18]. Serban B A, et al.developed a single application Cold-Chain independent drug delivery system for outer ear infection[19].In addition, there are many ways of ear canal care in life. (See Figure. 1).



(a) (b) (c) (d)

Figure 1. (a) Variant ways of ear canal nursing; (b) Variant ways of ear canal nursing;(c) Variant ways of ear canal nursing ; (d) Variant ways of ear canal nursing.

3. Design process

In the process of designing and building the EAR-NURSING interactive system, we invited experts from the Department of Otolaryngology, senior engineers in the AI field, and professors in design to jointly discuss the design and technology.

3.1. In-depth design discussions with experts

The research team conducted in-depth design discussions with three experts (2f, 1M, average age =45), including P1, an expert from the Department of Otolaryngology, Haizhu District People's Hospital, Guangzhou, China, P2, a senior engineer in AI field of Zhongkai College of agricultural engineering, and P3, a professor of design at Zhejiang University. The exchange seminar lasted about 2 hours. From problem mining, design conception, creative concepts, technical difficulties, and health knowledge of ear canal nursing to the realization of the design prototype, experts participated in the discussion of the whole design process, especially the in-depth analysis of the design prototype. They unanimously affirmed the innovation and feasibility of the design scheme: the problem points and entry points of the design truly reflect the objective problems, and the design of a human-computer interaction system for ear canal nursing using intelligent and digital technology will be more experiential, scientific, and forward-looking. The following suggestions were put forward:(i)P1, P2, and P3 suggested that the knowledge of ear canal health care should be widely popularized and the health cognition of subtle life such as ear canal care should be improved; (ii) P1, P2, and P3 all suggested that it was necessary to regularly check and record the health data of the ear canal and give timely feedback on the pathological data analysis; (iii)P1, P2, and P3 all found that the water that may enter the ear canal during the process of swimming and bathing may cause infection risk without timely care; (iv) p1 indicates that frequent cleaning of cerumen, unprofessional cleaning tools, and incorrect cleaning methods have become routine factors affecting the health of ear canal nursing;(v) P2 and P3 indicate that the technical feasibility and health care mode will become a difficulty in the interactive system of ear canal health care. After all, the effectiveness and health of the product interactive system will become the key points of the design.

3.2. Design objectives

Through in-depth design discussions with experts, the research team set the following design goals for the interactive system of ear canal health care: (1) the innovative interactive mode of visualization, intelligence, and data collection through an

application app, which not only improved the experience of ear canal health care but also collected the real-time live data of ear canal for analysis and feedback. As the questions (ii), (iv), and (v) in 3.1 are put forward, this is a very key design goal, that is, the innovative key to solving the problem; (2) The importance of ear canal health care in specific situations such as swimming and bathing, as well as the health awareness of subtle life such as ear canal care. As suggested in (i) and (iii) in 3.1, it will also become one of the design goals of the ear canal healthcare interaction system. (3) The software and hardware of the interactive system should achieve the design goal of low cost, high technology, high quality, and high efficiency because it involves the production cost of the interactive system and the possibility of successful commercial promotion.

4. Description of interactive system

Through in-depth discussions with experts and a series of design studies, the research team designed the system prototype EAR-NURSING.

EAR-NURSING interactive system is a combination of software and hardware (see Figure 2). The hardware system is a head-worn ear protector with the functions of rotation, expansion, image sensing, temperature sensing, massage, and disinfection. The software system is an application app that provides video learning, operation experience, mode selection, and data collection and analysis feedback. Software and hardware are connected via Bluetooth or Wi-Fi.

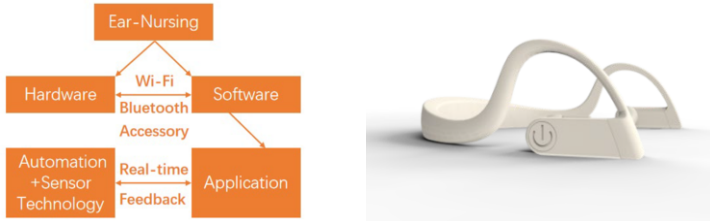


Figure 2. (a) Conceptual framework of ear nursing; (b) Ear care model.

4.1. Application App Design

The application app works with the running end of the actual hardware system. Select different operation modes of intelligent hardware through different interface designs (see Figure 3): A is the link mode; B is the rotation, adsorption, and stroking mode; C is music therapy and temperature control mode; D is data acquisition and analysis mode; E is video learning mode. To facilitate the user's operation experience, the interface design of the application app highlights the control comfort of the functional mode and the super explicit design of the functional symbols.

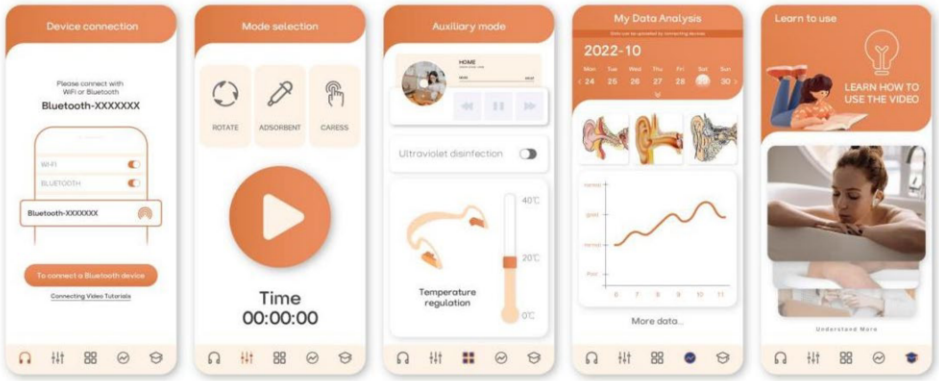


Figure 3: Interface of ear nursing app (left to right ABCDE) (a) link mode (b) rotation, adsorption and caress mode (c) music light therapy and temperature control mode (d) data acquisition and analysis mode (E) video learning mode.

4.2. Intelligent hardware headworn ear canal nursing simulator

The EAR-NURSING intelligent hardware system has a simple appearance and is made of silica gel material that meets the relative hardness. It is integrated with an image sensor (image information acquisition), a temperature sensor (to control the comfortable temperature of the ear canal between 28o-37o), a music player, and an automatic rotary telescopic and adsorption structure. The battery or charging module is installed in the middle of the headset. The part where the hardware fits the ear is designed as a suction nozzle, which is flexible and cute while meeting the comfort requirements (see Figure 4).

(a) **(b)** **(c)**

Figure 4. (a) Intelligent hardware side; (b) Intelligent hardware appearance;(c) Smart hardware details.

4.3. Human computer interaction and health care

The EAR-NURSING interactive system uses image sensors and temperature sensors (a micro-customized development board provided by Guangzhou Ninghou Cultural Innovation Technology Co., Ltd.), which can identify potential sensations from extreme conditions such as ear canal temperature and bacterial infection, and generate

pre-alarm signals to transmit to the central nervous system to generate data. Ninghou sensors send the digital conversion signal to the back-end server through the Wi-Fi module. The front-end page on the mobile phone obtains the digital conversion signal on the back-end server through an HTTP request, and outputs the real-time state to switch to the electrical signal. Smart hardware and application coordination start. As for the rotary telescopic rod and its disinfection and massage functions, it can be realized through conventional automatic components. Technical support makes the interactive system easy to use (see Figure 5).

(a) **(b)** **(c)**

Figure 5. (a) The technical principle of ear care interactive system; (b) Internal structure of ear care interactive system;(c) Application scenario of ear care interactive system.

5. Preliminary user study

To verify how users collaborate with the EAR-NURSING interactive system and their views on EAR-NURSING, we conducted a preliminary user study in two steps. In the first step, we used the method of a questionnaire survey (200 questionnaires were sent out and 157 valid questionnaires were recovered. After confirming the important entry point of the EAR-NURSING interactive system design and obtaining the precise demands of users, we entered the second step. We randomly invited five users a, B, C, D, e (2F, 3M, average age =32) in the local community. Each participant (PA, Pb, PC, PD, PE) evaluated all aspects of the interactive system design. All links are carried out under the guidance of designers and experimenters.

5.1. Procedure

After completing the first step of the questionnaire survey and statistical results, the experiment was carried out in the design studio scene. First of all, we briefly introduce the basic situation of this research, the design prototype, and the use of the interactive system. After that, participants are allowed to use the EAR-NURSING interactive system for experiments, and have a comprehensive communication and use test with participants in about 60 minutes. We also consider the accuracy and recall rate of data acquisition of image sensors and temperature sensors [20]. After the experiment, we suggested that participants take EAR-NURSING away for further experience and use. Five days later, we summarized the participants' feelings with the Likert questionnaire (Table 1) and conducted in-depth communication: (1) their feelings after using the ear nursing interactive system; (2) Design suggestions for future improvement of EAR-

NURSING interactive system; (3) The difference between traditional ear canal nursing methods and EAR-NURSING interactive system.

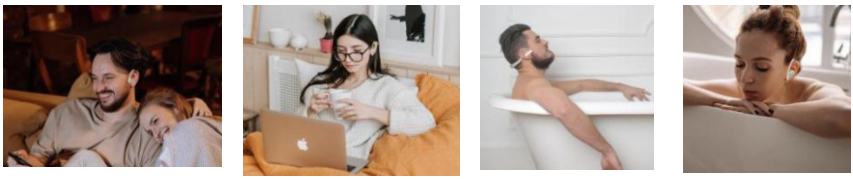
5.2. Results

As shown in Table 1 (7-point Likert scale) and user test (see Figure 6), all participants were willing to use the EAR-NURSING interactive system when nursing the ear canal and showed a high willingness to use the EAR-NURSING interactive system. However, they lack confidence in using an ear nursing interactive system to prevent and monitor ear canal bacterial infection during ear canal nursing, which needs further design improvement and more sample test results. For example, A, B, and D all indicate that the EAR-NURSING interactive system needs a larger base of user testing and market information feedback to make an objective and effective evaluation. A and C scored 6 points in Q (ii). They felt that the interaction mode and function of EAR-NURSING were too redundant. All five users pointed out that data collection, analysis, and timely feedback were necessary for the process of ear canal health care (the average score was 6.8). However, A and E believe that there is still a lot of practical verification for improving the health cognition of subtle life such as ear canal nursing. When participants were asked about the experience of using the EAR-NURSING interactive system and subsequent design improvements, E felt that the EAR-NURSING interactive system would be particularly interesting and have a good experience. He wanted to have it to quickly improve the health care of the ear canal. A. C and D put forward suggestions for design improvement: the real-time feedback of data acquisition is very good, and the comfort of head-worn intelligent hardware is also good. There may be problems such as the accuracy of sensor technology and the structure of the interactive system being too complex. In a word, all participants are willing to use EAR-NURSING interactive system in ear canal care. The results show that EAR-NURSING interactive system is an effective and innovative way to prevent and monitor ear canal health care.

Table 1. Results of user questionnaire.

Questions	Female A	Female B	Male C	Male D	Male E	Average
I Are you will to use EAR-NURSING interactive system while doing ear canal health care? (1:unwilling-7:willing)	7	7	7	7	7	7
II Is it easy for you to understand how to use EAR-NURSING interactive system while doing ear canal health care? (1:difficult-7:easy)	6	7	6	7	7	6.6
III What do you think of EAR-NURSING real-time data feedback, temperature control and ear canal care when doing ear canal health care? (1:useless-7:helpful)	7	7	6	7	7	6.8
IV Do you think that populating the knowledge of ear canal health care and improving the health knowledge of little life such as ear canal care can improve people's nursing awareness?	6	7	7	7	6	6.6

(1:useless-7:helpful) V Do you have confidence that you can improve your ear canal health by using EAR-NURSING interactive system while doing ear canal health care? (1:unconfident-7:confidential)	6	6	7	6	7	6.4



(a) **(b)** **(c)** **(d)**

Figure 6. (a)(b)(c)(d)(e)are user test scenarios.

6. Limitations and future work

Reviewing the design process of the study, the research team found some limitations and future work: (1) the number of discussion experts and the user base of system testing are insufficient, and more follow-up experimental data and design practice testing are needed for further verification; (2) In the process of technology application, the product structure is relatively complex, which will increase the manufacturing cost of the interactive system. In the future, the research team will further collect more accurate information and technical knowledge, design and improve the EAR-NURSING interactive system, and collect more data to demonstrate and invite more users to participate. It is expected that in future work, the research team will continue to explore the future of high integration of digital technology and design innovation and solve more hidden health problems for users.

7. Conclusions

The research team introduced the EAR-NURSING interactive system in detail, which can provide a more comfortable experience, intelligence and innovation in the health care of the user's ear canal. Through the digital sensor technology of data acquisition and analysis and real-time recording and feedback, the disease prevention and health monitoring of ear canal nursing were realized. EAR-NURSING interactive system carries out ear canal health care regularly according to the actual situation of the ear canal. Through the application app combined with the operation mode of intelligent hardware, it realizes the comprehensive experience of disinfection of telescopic head, rotation and expansion, adsorption of cerumen, gently stroking the ear canal, music therapy and real-time feedback of data collection and analysis. After designing and manufacturing the interactive system prototype, the results based on user testing show

that the EAR-NURSING interactive system is an innovative tool to prevent and monitor users' health care in the ear canal, and can improve users' health awareness of ear canal care. This may also provide more possibilities and research data for the research in the field of human-computer interaction, design and otology. It is reasonable to believe that EAR-NURSING interactive system can bring a more scientific, comfortable and reasonable user experience in people's ear canal health care.

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