# Development and usability evaluation of the mobile application for patients with chronic vestibular syndrome

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Master's thesis

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## Abstract.

### Background and Objectives

Chronic vestibular syndrome (CVS) is nonspecific and often goes untreated, which leads to disability and handicap. And recently, vestibular rehabilitation therapy (VRT) has been recommended as a first-line treatment for CVS. However, its accessibility is limited in China and many other developing countries for several reasons. Therefore, Internet-based approach may be used in situations such as long distance from the hospitals or with financial difficulty.

The study had four specific aims: Part1. Determination of the App modules and functions for CVS patients and development of the App prototype. Part 2. Acquisition of user experience. Part 3. Calculation of user requirements importance and determination of optimization strategy Part 4. Usability evaluation of the App

### Methods

In part 1, the researcher conducted two rounds of focus groups:8 specialists in the first group and 11 specialists in the second group, to explore the expected benefits and potential concerns of an App for CVS patients and determine the modules and functions of the App. In part 2, Face-to-face interviews with patients or their main caregivers were conducted in conferences. After the interview, patients were asked to fill out a general information questionnaire. Data collection and analysis were carried out simultaneously in this part. In part 3, based on the KANO model, the survey questionnaire was conducted to further analyze user requirements for App optimization. A combination of electronic and paper-based questionnaires was used. In part 4, usability was evaluated by quantitative research, using user testing and a questionnaire method. Twenty potential users were recruited in this part through the convenience sampling method

### Results

In Part 1 of the study, 8 modules were identified, including 20 specific functions in total. Based on the results of focus groups, an App prototype was developed over six months, encompassing design and coding. In Part 2 of the study (acquisition of user experience), interview results indicated that participants expressed positive evaluations regarding the "perceived usefulness" of this App. However, in terms of usability, there were several impediments, such as the presence of over-specialized content and intricate patterns. Regarding the optimization, 7 user requirements for enhancing user-friendliness were obtained. In part 3 of the study, three optimization suggestions for better usability were finally determined, including more understandable language, adding rehabilitation exercises time-reminder, personalized font size. The post-optimized design and content have garnered recognition from specialists. In Part 4 of the study, from a holistic perspective, the App exhibited favorable usability and garnered a notably high level of user satisfaction.

### Conclusions

This research designed and developed a mHealth App for CVS patients. Based on the KANO model, user experience and optimization requirements for the App prototype were acquired by interviews and importance of these requirements was calculated. Three optimization strategies for better usability were then determined. The usability of this App was evaluated finally and it exhibited favorable usability, garnered a notably high level of user satisfaction.



**Keywords:** Chronic Vestibular Syndrome, Vestibular Rehabilitation, Mobile Health Application; KANO Model; Usability Evaluation

## Abstrakti

### Tausta and Tavoitteet

Krooninen tasapainohäiriö (CVS) on epämääräinen ja usein hoitamaton tila, mikä johtaa vammaisuuteen ja haittaan. Viime aikoina tasapainoelinten kuntoutushoito (VRT) on suositeltu ensisijaiseksi hoidoksi CVS:lle. Kuitenkin sen saatavuus on rajoitettua Kiinassa ja monissa muissa kehitysmaissa useista syistä. Siksi internet-pohjaista lähestymistapaa voidaan käyttää tilanteissa, kuten pitkien etäisyyksien takia sairaaloihin tai taloudellisen vaikeuden vuoksi. Tämän tutkimuksen tavoitteena oli suunnitella ja kehittää mHealth-sovellus CVS-potilaille ja varmistaa sen käytettävyys.

### Metodit

Tutkimus koostui neljästä osasta: 1) Sovellusmoduulien ja -toimintojen määrittäminen CVS-potilaille ja sovelluksen prototyypin kehittäminen; 2) Käyttäjäkokemuksen hankkiminen; 3) Käyttäjävaatimusten tärkeyden laskeminen ja optimointistrategian määrittäminen; 4) Sovelluksen käytettävyyden arviointi.

### Tulokset

Osa 1: Sovellusmoduulit ja -toiminnot CVS-potilaille ja sovellusprototyypin kehittäminen. Lopulta tunnistettiin 8 moduulia, jotka sisälsivät yhteensä 20 tarkkaa toimintoa.

Osa 2: Käyttäjäkokemuksen hankkiminen. Haastattelutulosten perusteella osallistujat ilmaisivat positiivisia arvioita tämän sovelluksen "koetusta hyödyllisyydestä". Kuitenkin käytettävyyden osalta oli useita esteitä, kuten liian erikoistunut sisältö ja monimutkaiset mallit. Optimoinnin osalta saatiin 7 käyttäjän vaatimusta käyttäjäystävällisyyden parantamiseksi.

Osa 3: Käyttäjävaatimusten tärkeyden laskeminen ja optimointistrategian määrittäminen. KANO-mallin mukaan suurin vaatimusten tärkeys oli ymmärrettävämmässä kielessä, jonka jälkeen seurasivat harjoitusten aikamuistutukset, asianmukaiset ääniohjeet ja suurempi tekstinäyttö. Edellisten haastatteluiden sisällön ja strategioiden toteuttamiskelpoisuuden perusteella kolme optimointiehdotusta paremmalle käytettävyydelle määritettiin lopulta, mukaan lukien ymmärrettävämpi kieli, harjoitusten aikamuistutuksen lisääminen, henkilökohtainen fonttikoko. Jälkikäteen optimoitu suunnittelu ja sisältö saivat tunnustusta asiantuntijoilta.

Osa 4: Sovelluksen käytettävyyden arviointi. Kokonaisvaltaisesti sovellus osoitti suotuisaa käytettävyyttä ja sai huomattavan korkean käyttäjätyytyväisyystason.

### Johtopäätökset

Tämä tutkimus suunnitteli ja kehitti mHealth-sovelluksen CVS-potilaille. KANO-mallin perusteella käyttäjäkokemus ja optimointivaatimukset sovellusprototyypille hankittiin haastatteluilla ja näiden vaatimusten tärkeys laskettiin. Kolme optimointistrategiaa paremmalle käytettävyydelle määritettiin sen jälkeen. Lopuksi tämän sovelluksen käytettävyys arvioitiin, ja se osoitti suotuisaa käytettävyyttä ja sai huomattavan korkean käyttäjätyytyväisyystason.



**Asiasanat:** Krooninen vestibulaarinen oireyhtymä, vestibulaarinen kuntoutus, mobiilisovellus terveydenhuollossa; KANO-malli; käytettävyystutkimus

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## Abbreviations

| | |
|---|---|
| CVS | Chronic Vestibular Syndrome |
| VRT | Vestibular Rehabilitation Therapy |
| UI | User Interface |
| J2EE | Java 2 Platform Enterprise Edition |
| ISO | International Organization for Standardization |
| SUS | System Usability Scale |
| BPPV | Benign Paroxysmal Positional Vertigo |
| MD | Meniere’s Disease |

# 1 Introduction

## 1.1 Background

Chronic vestibular syndrome (CVS), commonly defined as having symptoms lasting for 3 months or more, is a nonspecific condition that often goes untreated, resulting in disability and impairment[1]. The prevalence of chronic vestibular symptoms in the adult population is estimated to be between 1.4 and 4.8%[2]. Although the precise causes of CVS are unclear, it is generally accepted that multiple factors are involved[3]. Review of the management of chronic vestibular syndrome indicated that no medication has well-established evidence nor is any medication suitable for long-term use[4]. This underscores the critical role of vestibular rehabilitation therapy (VRT), an exercise-based approach involving movements of the eyes, head, and body to promote vestibular compensation and habituation, first introduced in the 1940s[5]. VRT has recently been recommended as a primary treatment for chronic dizziness[6].

Despite the fact that researches have shown VRT is the most effective therapy for chronic vestibular syndrome, its availability is restricted in China and many other developing nations. There are several reasons for this underutilization. Firstly, the number of therapists with expertise in vestibular rehabilitation is alarmingly low, and many healthcare facilities do not have the required equipment or dedicated spaces to conduct VRT effectively. This shortage and lack of infrastructure impede the widespread adoption of VRT, leaving many patients without access to this crucial therapy. Secondly, from the patients' perspective, body constraints and financial burdens prevent regular clinic visits, especially for older adults, who make up the majority of the patients. For these patients, the costs associated with travel, as well as the logistical difficulties of frequent appointments, can be prohibitive. These barriers are exacerbated in remote or underserved regions where healthcare resources are sparse. In light of these challenges, internet-based approaches to VRT offer a promising solution.

Mobile health (mHealth) technology has emerged as a promising tool for fostering patient engagement in healthcare management. Specifically, mHealth tools exhibits substantial potential as a potent mechanism for instigating health behavior modifications, particularly in health prevention and self-management contexts, owing to its omnipresence, portability, and advanced computational capabilities[7]. Consequently, given the great potential of mHealth, it is not surprising that current estimates suggest there are more than 165,000 mHealth applications (Apps)[8] . Although the use of mobile application as a tool to help people with other chronic conditions has been explored and its effectiveness has been proved [7, 9] as well, there remains a conspicuous absence of research concerning mHealth interventions tailored for individuals with CVS. Therefore, addressing this lacuna necessitates the development of dedicated App catering to this specific demographic.

To sum up, given the significance of vestibular rehabilitation for patients with chronic vestibular syndrome and the potential of mHealth tools for health education and self-management, this research aims to design and develop a specialized App tailored to individuals grappling with chronic vestibular syndrome. Then the subsequent optimization of this App will be guided by the KANO model, improving user friendliness and satisfaction, followed by a rigorous evaluation through usability testing and questionnaire survey. If this study yields expected effects and is accepted by the patients, it will be an innovative strategy for management of chronic vestibular syndrome.

## 1.2 Theoretical significance

Although mobile health technology is quite mature, there is few research focused on patients with chronic vestibular syndrome. Therefore, this study theoretically provides a new method for research in the field of vestibular rehabilitation by using scientific methods to develop and optimize the application prototype of vestibular rehabilitation and verify its usability.

## 1.3 Practical significance

Cognition of chronic vestibular syndrome and utilization of vestibular rehabilitation is limited in China and many other developing countries until now for some reasons. Developing an App for patients with chronic vestibular syndrome could increase public awareness of the condition and assist patients with vestibular rehabilitation at home rather than frequent hospital visits.

What’s more, the beneficiary of this App are not only patients, but also caregivers and therapists. Therefore, it can also help medical workers with patient management, which will improve the efficiency of the hospital.

# 2 Literature review

## 2.1 Overview of chronic vestibular syndrome

### 2.1.1 Epidemiology and pathogenesis of chronic vestibular syndrome

Chronic vestibular syndrome is a group of clinical syndromes characterized chronic vertigo/dizziness or instability that lasts for months to years, usually with persistent vestibular system dysfunction (visual oscillations, nystagmus gait and instability)[10]. There are also signs and symptoms suggesting dysfunction of the cochlea or central nervous system.

CVS is a very challenging problem[11]. Each year around 1 in 20 people in the general population experiences vertigo[12]. Around 80% of these people affected by vertigo find that it severely impairs their daily functioning. Since the symptoms of vertigo prevent many people from working, as well as resulting in an increase in the risk of falling and a high use of healthcare services, vertigo also represents a substantial economic cost.

CVS usually presents a progressive, worsening course, and sometimes includes a state of unstable incomplete recovery after acute vestibular disease or a state of persistent symptoms between episodes of episodic vestibular disease[13]. These diseases mainly include bilateral vestibular dysfunction, Persistent postural perceptual dizziness (PPPD), psychogenic dizziness and so on. These peripheral vestibular disorders induce an important innate repair mechanism known as vestibular compensation, which aids functional recovery after damage to the vestibular system[14]. However, there is a large inter-individual variation in the rate and level of recovery. Chronic vertigo occurs when natural vestibular compensation fails[10].

### 2.1.2 Treatment of chronic vestibular syndrome

Vestibular rehabilitation is now considered the preferred treatment for patients with chronic vertigo and is recommended by USA[15] clinical practice guidelines. In spite of this guidance, anti-vertigo drugs such as Betahistine are commonly prescribed, and vestibular rehabilitation is hardly used to treat chronic vertigo. An observational study of patients with vertigo from 13 different European countries (4294 participants) found that Betahistine was prescribed to more than two thirds of patients with vertigo in general practice at the first consultation and was still being used six months later[16]. In contrast, surveys of general practitioners in the Netherlands (n=426)[17] and UK (n=53)[18] found that only 5.8-6.8% used vestibular rehabilitation.

## 2.2 review of vestibular rehabilitation

### 2.2.1 The mechanism and contents of vestibular rehabilitation

The powerful compensatory potential of vestibular system and the great plasticity of balance system are the foundation of vestibular rehabilitation[19]. Vestibular adaptation, vestibular acclimation and sensory substitution are known to be the main mechanisms of vestibular rehabilitation[20]. The unique value of vestibular rehabilitation is to improve the ability to see clearly during movement, reduce vertigo symptoms, reduce instability/imbalance, help patients return to normal life, and reduce social alienation[21].

Vestibular adaptation needs to be modified by vestibular - ocular reflex exercises. Gaze stability training is a classic movement of vestibular rehabilitation, which requires two sensory stimuli-visual and head movements[22]. Vestibular adaptation is induced by error signals caused by retinal slide to increase the gain of vestibular response[21], the most effective is that the eye is fixed to the visual target when the head moves in the horizontal and vertical plane, and the exercise on the roll plane has little change in vestibular - ocular reflex gain[19].

Vestibular acclimation is a central learning process that is primarily used for symptoms of visual/motor sensitivity[23]. Repeated exposure to symptom-induced situations, including specific motor or visual environments, can gradually reduce response intensity, which is the basis of acclimation training, the specific mechanisms and neural circuits are not yet understood. Once established, the habit can be maintained for a period of time, and repeated training can be maintained for a longer time. However, bilateral vestibular dysfunction is not an indication of conditioned exercise, since vestibular conditioning is designed to reduce unwanted responses to vestibular signals and does not improve gaze or postural stability[24]. It is also important to note that older adults should avoid certain conditioned movements (such as rising quickly) that may cause postural hypotension. Early acclimatization training can aggravate symptoms and lead to reduced compliance, which should be fully explained in clinical application[25].

Sensory substitution is an alternative mechanism to replace the impaired vestibular function through vision, proprioception, neck-eye reflex, etc.[26]. Because of the frequency characteristics, the application environment of sensory substitution is limited. For example, in poor lighting environment and uneven ground, visual and proprioceptive substitution effect is obviously insufficient. The neck-eye reflex also works only at very low frequencies (<0.5 Hz) and does not contribute much to visual stability during head movements[27]. For unilateral vestibular dysfunction, controlled balance can be achieved through vestibular compensation, and sensory substitution is of little significance. For patients with bilateral vestibular function loss, sensory substitution obviously plays an important role, but the specific mechanism is still little known, and overuse of vision is thought to play a major role[28].

In most cases, postural stability exercises are an integral part of vestibular rehabilitation, and the core idea is to adequately challenge more difficult balance tasks without falling[29]. The training methods can be summarized as: standing, walking and turning under the condition of removing or changing visual cues and interfering with proprioception (such as foam pad or moving platform)[30], and repeated reinforcement based on the theory of motor learning to improve the comprehensive use of visual and somatosensory information, and enhance the formation of vestibular signals and central preprogramming. Gait speed < 0.8m /s indicates the need for gait training[21]. During gait exercises, head movements (such as nodding and shaking) can be combined at the same time to correct the "protective strategy" of vestibular dysfunction patients who are accustomed to not turning their heads during movement, and excessive fixation can also be corrected[31].

Regarding the timing and frequency of vestibular rehabilitation, the guidelines[32] recommend that patients with acute/subacute vestibular dysfunction perform gaze stabilization exercises at least 3 times per day, with a total exercise time of no less than 12 minutes per day, and patients with chronic vestibular dysfunction at least 20 minutes per day. For patients with acute and subacute vestibular dysfunction, there is no specific dose of balance exercise recommended for the time being[33]. Patients with chronic vestibular dysfunction should perform balance exercise for at least 20 minutes a day for at least 4-6 weeks[32]. The patient's symptoms disappear, or the condition is stable and the curative effect has reached a plateau, which can be used as an indication to stop vestibular rehabilitation training. However, if the patient's compliance is poor, the clinical condition continues to deteriorate or the vestibular function state fluctuates (such as Meniere's disease activity phase), and there are psychosomatic problems, which hinder the vestibular rehabilitation effect, the rehabilitation practice can be stopped[34].

### 2.2.2 Clinical research status of vestibular rehabilitation

The efficacy of vestibular rehabilitation is not affected by the patient's age, gender, etc[35]. Whether it is peripheral, central or mixed lesions, as long as the patients with stable nonprogressive lesions and spontaneous mal-compensation, vestibular rehabilitation can be used as the primary treatment[36].

The effect of vestibular rehabilitation on unilateral/bilateral vestibular dysfunction is the most common research direction[37], and the main research results are fully summarized in the "Practice Guide for Vestibular Rehabilitation in Patients with External vestibular Dysfunction" published in 2016[15]. Strong evidence (3 randomized controlled trials) shows that: Vestibular rehabilitation can bring clear and substantial benefits for patients with acute or subacute unilateral vestibular dysfunction, and the earlier the start, the better; (2) Patients with chronic unilateral/bilateral vestibular dysfunction can also benefit from vestibular rehabilitation; (3) Saccades and smooth tracking exercises alone are not effective and may also waste time and delay effective treatment[15]. After 2016, a number of high-quality randomized controlled studies have been carried out in succession. Additional evidences include: (1) vestibular neuritis is equally effective in vestibular rehabilitation as hormone therapy. Hormone seems to accelerate the remission of acute symptoms, but has no additional benefits for long-term prognosis[38, 39]; Are vestibular rehabilitation and hormonal therapy more beneficial? One study concluded that combination therapy has no greater benefit than monotherapy[39], and another concluded the opposite[40], but these differences do not seem to shake the importance of vestibular rehabilitation in the treatment of vestibular neuritis. (2) Vestibular rehabilitation can significantly reduce the number of falls in the elderly[41]. The experimental group received dynamic balance and visual motor training, while the control group received no rehabilitation intervention and only encouraged walking to improve general physical condition. At 12-month follow-up, the number of falls in the experimental group decreased from 10.96 in the first year before rehabilitation to 3.03, while the number of falls in the control group had no significant change. (3) For vestibular rehabilitation of the elderly with balance disorders (using dynamic balance table), the effect of 5 courses is equivalent to 10 courses, and this study has answered the question of rehabilitation duration for the first time[42].

However, the popularization and promotion of vestibular rehabilitation is a universal challenge worldwide. Foreign surveys have found that less than 3% of patients have access to vestibular rehabilitation services[43]. The research and practice of vestibular rehabilitation in China started not late. Since 2003, a number of professional articles have been published[44, 45], and colleagues in the industry have been fully prepared in terms of knowledge system. But its accessibility is limited in China and many other developing countries for some reasons.

Therefore, how to establish an intelligent, remote and home-based practice model to improve the accessibility of vestibular rehabilitation services is one of the new research hotspots.

## 2.3 Overview of mHealth application

### 2.3.1 Research status of mHealth application

Nowadays, mobile phones are so prevalent that they are now an integral part of daily life[46]. With the widespread availability of these devices and the convenience they offer, mobile health (mHealth) has gained unprecedented traction[47].

mHealth refers to the use of mobile technologies to enhance and support public health initiatives[48, 49]. This approach has evolved into a vast tool that empowers patients to take charge of their own care, fostering greater patient-centred care and contributing to an improved understanding of health conditions, ultimately shifting public perceptions in a positive direction[50].

Currently, over 325,000 health apps can be found on app stores across various mobile platforms[51]. Researchers have systematically evaluated highly-ranked apps designed for users across all age groups[52-56]. In various studies, the analysed apps offered minimal features, primarily emphasizing information dissemination or educational purposes, along with tools for tracking and self-monitoring activities (such as counting calories or steps, using calendars and so on)[57].

Despite advances in technology, all-encompassing, multifunctional mobile applications are still uncommon[58]. Many free apps, in particular, lack features like exercise routines, dietary plans, individualized feedback, or access to certified professionals[56, 59]. The advent of advanced smartphone technologies has significantly enhanced the potential of mobile health solutions. A health App today can track various personal metrics such as heart rate, mood, activity levels, sleep habits, diet, hydration, and even sexual behaviour throughout the day. As a result, the real potential of mobile health apps is in their ability to customize and adjust interventions for behaviour change in real time, leveraging user and environmental data to enhance health[60].

While mobile applications have been examined for their effectiveness in managing various chronic conditions, there has yet to be a study focused specifically on individuals with chronic vestibular syndrome. The absence of such research highlights a significant gap in the current literature.

To sum up, if this study demonstrates that mobile applications can effectively enhance balance function and emotional well-being for those with chronic vestibular syndrome, it could introduce a pioneering approach to managing this condition. Such findings would not only contribute to the existing body of knowledge but also potentially offer a novel and practical solution for improving quality of life in this patient population.

### 2.3.2 Usability evaluation of mHealth application

With the promulgation of relevant policies, mobile medical Apps also show a blowout growth. How to improve the availability level of mobile medical Apps and improve users' satisfaction with mobile medical has become an important issue facing the development of mobile medical[61].

Until now, 16 evaluation tools related to mobile health usability were identified. 13 mHealth usability assessment tools from abroad, they are the mobile Health availability assessment scale (MAUQ)[62], MARS[63], uMARS[64], Health-ITUES[65], TUQ[66] SUTAQ[67], TSUQ[68], TSQ[65], TMPQ[69] and 3 unnamed scales. Five other assessment tools are from China, mainly developed in the form of evaluation index system. Among all these 16 tools, 14 evaluation tools have been verified by the developers, and the verification methods are mainly questionnaire survey and experimental method. Of the 16 tools, 4 were developed based on telemedicine systems. In addition, the Italian National Institute of Health proposed the telemedicine quality control process TM-QC[70]. The assessment object of Health-ITUES is adult AIDS patients, and the format of the scale is open, which will undoubtedly bring some difficulties to researchers who have no experience in using questionnaires[14]. SUTAQ, TSUQ, and TSQ were developed to understand patient satisfaction, which is just one of many metrics used to assess availability[71]. Usability assessment questionnaires developed from a healthcare perspective include TUQ and uMARS[72]. MARS was developed and designed for researchers, and uMARS is based on MARS. Although MARS and uMARS have been widely used by researchers to evaluate the quality of a certain type of health APP in recent years, MARS and uMARS focus on evaluating the quality of mobile medical Apps, which reduces the measurement of application effectiveness and user experience to some extent[73].

In addition, due to the different attributes of the evaluated products, researchers often use different evaluation indicators. Demiris[69] found that privacy, data confidentiality, use and reliability of telemedicine are important factors affecting patients' acceptance of telemedicine care. Leming Zhou[62] et al. developed and verified the mobile health usability questionnaire MQUA, which included three indicators: ease of use, interface and satisfaction, and usefulness. Stoyan[63] extracted 372 clear criteria for evaluating Web or application quality through literature analysis, and summarized them into four objective quality scales (engagement, functionality, aesthetics, and information quality) and one subjective quality scale. The telemedicine usability evaluation scale TUQ summarizes the important roles of usefulness, ease-of-use and learnability, interface quality, interaction quality, reliability, satisfaction and future use on its usability[66]. Chen Yue [74] found that the utility of APP, professional ability of perceived consultation, e-health literacy and perceived health threat had a positive impact on users' willingness to continue using online consultation APP. Hou Xiong[75] et al. explored the service demand of Internet hospitals based on the KANO model and found that assurance, type, reliability, reactivity and caring affect users' evaluation of service quality of Internet hospitals. It can be seen that there is no clear classification standard for existing usability indicators, and the selection and naming of usability indicators are also different.

Therefore, many researchers recommend a more widespread use of International Organization for Standardization (ISO) guidelines and techniques[76] to guide usability evaluations[77], which could help expanding usability testing to be more systematic and complete can help build a science of mHealth usability. More standardized, comprehensive approaches would improve methodological consistency, making it possible to begin comparing findings across mHealth application evaluations[78]. Researchers need to assess the full set of recommended measures—effectiveness, efficiency, and satisfaction—to obtain a more thorough picture of the usability of any application[78, 79]. Specifically, effectiveness refers to what extent the user can achieve a goal with accuracy and completeness, while efficiency means the level of effort and resource usage which is required by the user in order to achieve a goal in relation to accuracy and completeness. And satisfaction means the positive associations and absence of discontent that the user experiences during the performance. In that vein, my research employs ISO 9241-11 and techniques to evaluate the usability of the Health app .

### 2.3.3 Research status of mHealth for vestibular rehabilitation

The low clinical popularizing rate of vestibular rehabilitation is a common problem worldwide[21]. Mobile health Apps can alleviate this problem to some extent[80].

A Singapore study[81] has preliminarily demonstrated the feasibility and usability of the mobile VRT in healthy older adults. But this study has some limitations, for example, only English-speaking old adults were recruited. There are also studies that verify vestibular rehabilitation based on WeChat platform[82]. The results showed that the patients' homeostasis function and vestibular activity were improved. Vugt VV et.al[83] developed “Vertigo Training”, an internet-based VR application, and performed a large randomized controlled trial, which showed that patients in both the stand-alone group and blended VR group experienced a clinically relevant decrease in vestibular symptoms, dizziness related impairment, anxiety, and depressive symptoms up to 36 months follow-up[84]. Besides, there are few mobile medical applications for patients with vestibular dysfunction, and there are no widely used Apps in Apple Store and Google Play.

Therefore, if this study has expected effect, it will be an innovative strategy for management of chronic vestibular syndrome, which could improve the accessibility of VRT, enhance patients' chronic symptom management ability and save medical resources.

## 2.4 Overview of focus groups

Focus groups originated from sociology, which has been widely applied since the 1980s[85]. They are a form of group interview that capitalizes on communication between research participants in order to generate data[86]. The method is particularly useful for exploring people's knowledge and experiences and can be used to examine not only what people think but how they think and why they think that way[87].

Previous studies and practices have shown that conducting a focus group requires a high level of resources and endeavors[88]. Firstly, a clear and specific purpose statement is needed in order to develop the right questions and elicit the best information from focus group discussions[89]. Kitzinger[86] et al. indicated that focus groups were better used to explore specific or narrowly-focused topics; otherwise, the data obtained was likely to be diffused, thus making data analysis a difficult task. Then, a discussion guide is needed to be decided before the focus group. A well-designed focus group guide should allow the flexibility to pursue unanticipated yet relevant issues that may be generated during the discussion[90].

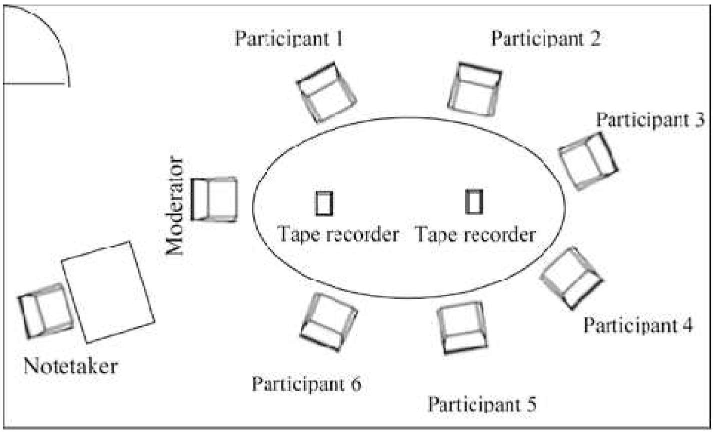



Figure 1 Focus group seating plan

Focus groups were originally harnessed within sociology studies. In the past several decades, focus groups have been found to be particularly apt in solving a wide range of health and medical related issues due to the fact that most health-related conditions are created by social environments and made within the social context[91]. Thus, focus groups are a popular method for assessing public experience and understanding of illness[92], identifying ideas concerning health-risk behaviors and danger, and discovering the public's perception of causes of diseases[93]. Focus groups are also exceptionally effective for study of sensitive issues as well as issues that are difficult to access, such as acute mental distress, HIV/AIDS, or sexual health issues[94]. They can also be used to gain insights into people's experiences of ill and health services[95], and explore the attitudes and needs of healthcare providers.

In summary, substantial research underscores the indispensable role of focus groups in medical domain, particularly when the objective is to gain and elucidate comprehensive perspectives and opinions. Therefore, given the highly specialized nature of CVS and VRT, coupled with only the few research within this domain concerning mobile Apps, focus groups with specialists were adopted in this research to understand their attitudes towards mobile application for patients with CVS and identify the desired functions and characteristics of this application.

## 2.5 Overview of KANO model

The Kano model was proposed in 1984 by Noriaki Kano, a Japanese quality management master. This model can reflect the relationship between service quality and user satisfaction more comprehensively[96]. The method for solving the non-linear relationship between meeting user requirement and overall user satisfaction using Kano consists of the following three steps: Kano questionnaire, Kano evaluation table, and Kano category results[97].

After identifying user requirements, develop structured questionnaires. According to the analysis of user requirements, the Kano questionnaire is made, and both positive and negative questions are raised for a single functional demand (provide this function/not provide this function)[98]. The demands are categorized into five items: "like", "should be", "neutral", "tolerable", and "dislike" (as shown in the Table 1)[99].

Table 1 Kano Questionnaire

| Function | Like | Should be | Neutral | Tolerable | Dislike |
|---|---|---|---|---|---|
| Provide | | | | | |
| Don’t provide | | | | | |

Kano model explains that for some user attributes, user satisfaction is dramatically increased with only a small improvement in performance, while for other user attributes, user satisfaction is increased only a small amount even when the product performance is greatly improved[100]. Fig. 2 shows how the Kano model distinguishes five types of product requirements that influence customer satisfaction in different ways[101], and each requirement type is described in the following:

*Must-Be Requirements (M)*: These are basic criteria of a product since, if they are not fulfilled, the customer will be extremely dissatisfied. However, their fulfillment will not increase satisfaction since the customers take them for granted[102].

*One-dimensional Requirements (O)*: In this category of requirements, customer satisfaction is proportional to the level of fulfillment of need—the higher the level of fulfillment, the higher the customer’s satisfaction and vice versa. One-dimensional requirements are usually explicitly demanded by the customer.

*Attractive Requirements (A)*: These are the product criteria that have the highest influence on customer satisfaction with a given product. Customers may not expect them, however, fulfilling those leads to more than proportional satisfaction. On the other hand, if they are not met, there is no dissatisfaction[102].

*Indifferent Requirements (I)*: This category means that the customer is indifferent to this product attribute and is not very interested in whether it is present or not.

*Reverse Requirements (R)*: This means that, not only do the customers not desire that product attribute, but they also expect the reverse of it[102].

Finally, the research results are classified and counted according to the Kano evaluation table to obtain the demand attributes. The demand categories are determined and filtered into must-have, expected, and attractive user demands based on the maximum frequency of their corresponding categories A, O, M, I, and R while removing indifferent and reverse attributes[99].


Figure 2 Kano Model[103]

Table 2 Kano evaluation list

| User requirements | | Negative questions | | | | |
|---|---|---|---|---|---|---|
| | | Like | Should be | Neutral | Tolerable | Dislike |
| Positive questions | Like | Q | A | A | A | O |
| | Should be | R | I | I | I | M |
| | Neutral | R | I | I | I | M |
| | Tolerable | R | I | I | I | M |
| | Dislike | R | R | R | R | Q |

KANO model offers a structured approach to understanding and categorizing user requirements based on their potential impact on the satisfaction, which has been harnessed in various domains[104]. Currently, KANO model has been extensively applied within the medical field along with the development of eHealth in recent years, particularly in the design and optimization of digital healthcare products. Mu-Chen[105] utilized KANO model to improve service quality and customer satisfaction in pharmaceutical logistics in Taiwan. Christin[106] established the prioritization of quality principles for health Apps using the Kano model, within a total of 9503 members of two German professional societies in the field of orthopedics.

Through a review of the relevant literature on the KANO model, it is evident that in recent years, the KANO model has been extensively applied in the fields of medical product design and user satisfaction assessment. Consequently, this research employed the KANO model to further optimize the application prototype, aiming to better align the App with user requirements.

## 2.6 Summary of the literature review

Chronic vestibular syndrome is a group of clinical syndromes characterized chronic vertigo/dizziness or instability that lasts for months to years, usually with persistent vestibular system dysfunction. Vestibular rehabilitation is now considered the preferred treatment for CVS patients and is recommended by clinical practice guidelines. However, the popularization and promotion of vestibular rehabilitation is a universal challenge worldwide. Therefore, how to establish an intelligent, remote and home-based practice model to improve the accessibility of vestibular rehabilitation services is one of the new research hotspots.

The use of mobile application as a tool to help people with other chronic conditions has been explored and its effectiveness has been proved as well, and it can serve as an important direction for the popularization and promotion of vestibular rehabilitation, which could improve the accessibility of VRT, enhance patients' chronic symptom management ability and save medical resources.

Focus groups have been increasingly employed to solve a wide range of health-related issues in recent decades and demonstrated good efficacy. Therefore, focus groups were adopted in this research to identify the desired functions and characteristics of the application, as the basis of design and development.

The amalgamation of qualitative and quantitative research, utilizing the Kano model, has evolved into a mature framework which has been employed in numerous product design and improvement endeavors. Therefore, Kano model is applied in this research to optimize the App prototype for better usability.

In addition, many researchers recommended a more widespread use of usability evaluations in the mHealth field because more standardized, comprehensive approaches would improve methodological consistency and make it possible to begin comparing findings across mHealth application evaluations. Therefore, three indicators, including effectiveness, efficiency, and satisfaction are adopted in this research to evaluate the usability of this App.

## 2.7 Definition

### 2.7.1 Vestibular rehabilitation therapy

Vestibular rehabilitation therapy (VRT) is a training-based program for patients with vestibular dysfunction. It can also be understood as a series of repeated head, neck and body exercises developed by professionals, which includes a combination of four main elements: gaze stability exercises, habituation exercises, balance and gait training in various conditions, general endurance training[107].

### 2.7.2 Mobile health application

The US Food and Drug Administration (FDA) defined a mobile health application as a software function deployed on a mobile platform that meets the definition of a medical device[108].

### 2.7.3 Usability

Usability is defined as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use by International Organization of Standardization (ISO) in the ISO 9241-11[76]. Specifically, effectiveness refers to what extent the user can achieve a goal with accuracy and completeness, while efficiency means the level of effort and resource usage which is required by the user in order to achieve a goal in relation to accuracy and completeness. And satisfaction means the positive associations and absence of discontent that the user experiences during the performance.

# 3 Research Purpose

## 3.1 Overall aim

Design and develop a mHealth App for patients with chronic vestibular syndrome, further optimize and verify the usability of the App.

## 3.2 Specific goals

1) Conduct focus groups to determine the functions and modules of the mHealth application for patients with CVS. And then develop an App prototype cooperated with software developers based on the results of focus groups.

2) Interviews with end users of the App, including CVS patients and their main caregivers to explore their use experience and optimization requirements for the App prototype.

3) Classify and calculate the importance of these optimization requirements base on KANO model, then determine the optimization strategy and complete the optimization process.

4) Verify the effectiveness, efficiency, and satisfaction of the App to gain an understanding of its usability.

## 3.3 Roadmap

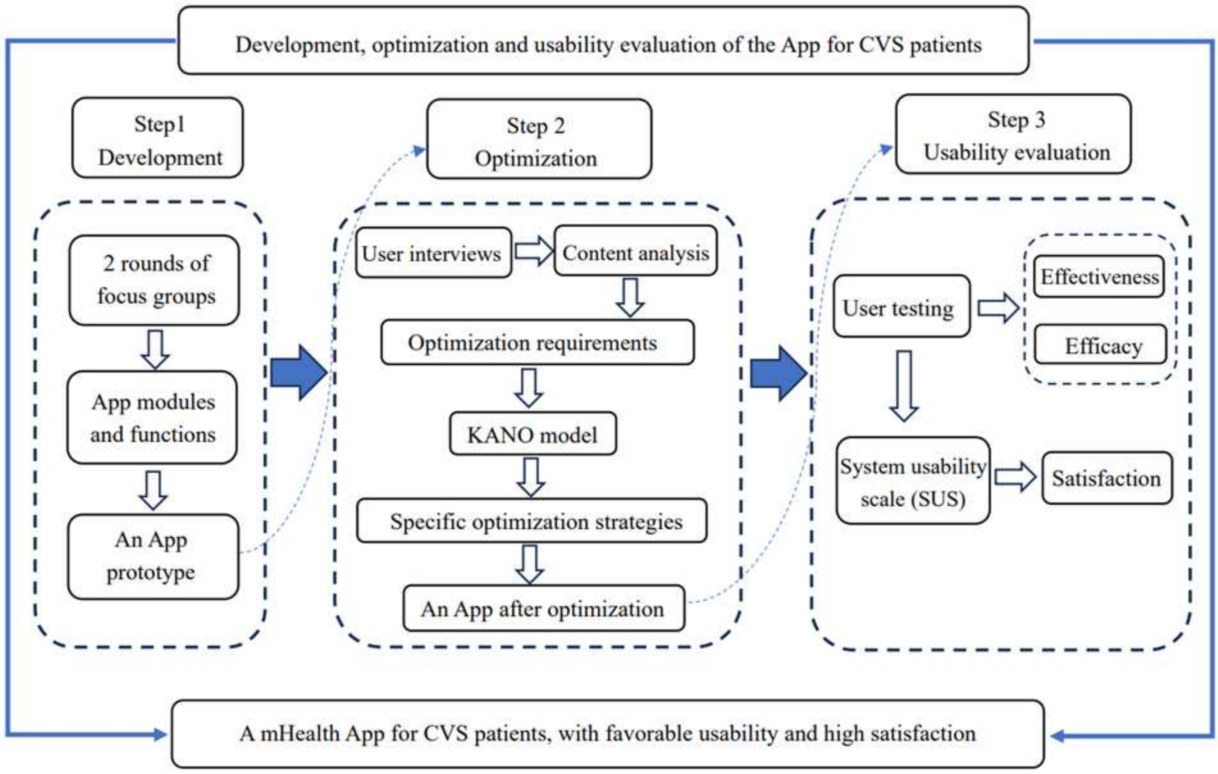



Figure 1 Roadmap

# 4 Development of application prototype

## 4.1 Research methods

### 4.1.1 Study design

Qualitative study, using focus groups of expert panels.

Given the highly specialized nature of CVS and VRT, coupled with only the few research within this domain concerning mobile Apps, focus groups with specialists were adopted in the first part of this research to understand their attitudes towards mobile application for patients with chronic vestibular syndrome and identify the desired modules and functions of this application.

### 4.1.2 Research participants

Purposive sampling method was employed to recruit the participants.

Inclusion criteria for specialists in the otolaryngology or neurology domain:

1) Physicians or professors who have more than ten years of working experience in the field of chronic vestibular syndrome;
2) Master degree or above, intermediate title or above;
3) With a comprehensive understanding of mHealth applications and a pronounced interests in this field.

Inclusion criteria for specialists in the field of software development:

1) People who have more than five years working experience for the software development;
2) People who have experience for the development of mHealth developments;
3) The products have been used more than 10 million people in total;
4) Bachelor degree or above.

Totally, 19 experts were invited in the study. Previous review[109] indicated that the group should not be so large as to preclude adequate participation by most members nor should it be so small that it fails to provide greater coverage than that of an individual interview.

Therefore, 19 experts were divided into 2 focus groups, which has 8 specialists in the first group and 11 specialists in the second group.

### 4.1.3 Research sites and tools

2.1.3.1 Research sites

When setting up a focus group session, the physical setting was considered carefully. The venue must be comfortable and conducive to discussion. In selecting a focus group site, it is also important to make it geographically convenient for the participants. Often the tape-recorder will pick up background noise, thus, the discussion room should be free from outside distractions.

Therefore, considering the comfort and geographically convenient for the participants, the first group was conducted in the conference room of the Second People's Hospital of Shenzhen, and the second group was conducted in the outpatient conference room of Eye and ENT hospital of Fudan University.

2.1.3.2 Research tools

Discussion guide (Appendix A): Based on the research question and objective of this section, the preliminary discussion guide was designed, and the formal version was adjusted after pre-testing with several “mock” focus groups conducted by research teams. The formal discussion guide was divided into three parts, including opening questions, topic questions and additional questions. Questions were open-ended, comprehensible, and nonthreatening.

### 4.1.4 Data collection

After determining the discussion guide, the researcher initiated contact with renowned experts in the field of chronic vestibular syndrome and vestibular rehabilitation in China, as well as the software engineers, through telephone or email. In the initial contact, the researcher provided a comprehensive explanation of the study's objectives, procedures, and significance. If the experts expressed interest and willingness to participate, they were asked to sign an informed consent (Appendix D). Subsequently, the researcher invited them into a WeChat group chat, where consensus was reached collaboratively regarding the timing and location of the research. This procedural approach was consistently applied to two rounds of focus group sessions. Focus groups were conducted in the pre-established conference room and participants were arranged to sit around a table to enable them to see and hear one another.

Each focus group required two staff members: one to moderate the discussion process and another to take notes. In this study, a master’s student served as the moderator, while the role of note-taker was assumed by another graduate student of the research team. The moderator's duties included steering the conversation and managing the group dynamics to ensure balanced participation from all members. To prevent any participant from dominating the discussion, the moderator would direct questions to less vocal individuals, promoting a more equitable exchange of ideas. Meanwhile, the note-taker was responsible for meticulously recording the dialogue, including the tone of the conversation, the sequence of speakers, and specific comments made by each participant. Accuracy in capturing this information was crucial for the integrity of the study.

The focus group began with a welcome. The moderator introduced herself and the notetaker, and gave a brief overview of the topic of discussion and objective of research and ground rules, then explained the session was recorded in recorder pen throughout. During the formal discussion, the discussion guide provided the moderator with topics and issues that were to be covered at some point. However, it was not the equivalent of a survey instrument, and was not to be followed in detail or even necessarily in order strictly.

The discussion was terminated when no new information emerged from the statement and duration of each discussion was about 120 minutes. After the focus group, experts were individually inquired regarding their feelings of the session and whether they had any unexpressed viewpoints.

### 4.1.5 Data analysis

Analysing focus group data relies heavily on the participants' actual words and behaviours. In this study, the core of the analysis was grounded in interpreting the verbal and non-verbal responses of the participants, which provided insight into the research query. By examining these responses closely, researchers can draw meaningful conclusions and understand the underlying themes or patterns relevant to the study.

Specifically, the first step was to produce a verbatim transcript of the entire discussion according to the recordings.  Then the handwritten notes were read carefully to fill in other important information. The next step was coding the data in the transcripts, using conventional content analysis method[110], which involved sorting the data and assigning them to categories and themes. The data coding was carried out by two researchers separately. Finally, the two researchers compared the codes and themes, resolved differences in coding through discussion.

Based on the results of focus groups, an App prototype for CVS patients was developed over a period of six months.

### 4.1.6 Ethical considerations

The Institute of ethical review board of Eye and ENT Hospital of Fudan University have approved this study (reference No. 2019091). Before the participation, specialists were asked to sign an informed consent form and they were informed that they could decline to answer the questions or withdraw from the study at any time. In any time, only the research team had access to the discussion recordings and written materials, and the personal information of the specialists would not be disclosed in any form.

### 4.1.7 Quality control

1) The researcher served as the moderator and principal investigator, overseeing the progression of the focus group and ensuring the acquisition of maximal information.

2) In the process of data sorting and analysis, the verbal and non-verbal statements of all interviewees in this study were analysed comprehensively and clearly by two researchers, ensuring the authenticity and representativeness of the results.

3) During the development phase, researchers and software development teams convened regularly on a weekly basis, assessing the progress of the development and scrutinizing its milestone achievements.

## 4.2 Research results

### 4.2.1 Results of focus groups

#### 2.2.1.1 Demographic data

In total, 2 focus groups consisting of specialists (N1=8, N2=11) were conducted in October and December 2022, respectively. The general information of expert panels is shown in Table 3.

Table 3 Expert panels demographic data (N=19)

| | Age | Gender | Expert Field | Education Background | Professional Title |
|---|---|---|---|---|---|
| **Group 1** | | | | | |
| S1 | 55 | Male | Otolaryngology | PhD | Senior |
| S2 | 63 | Male | Otolaryngology | PhD | Senior |
| S3 | 59 | Male | Otolaryngology | PhD | Senior |
| S4 | 46 | Male | Otolaryngology | PhD | Intermediate |
| S5 | 53 | Male | Neurology | PhD | Senior |
| S6 | 62 | Male | Otolaryngology | PhD | Senior |
| S7 | 44 | Male | Otolaryngology | PhD | Intermediate |
| S8 | 31 | Female | Software engineer | Master | NA |
| **Group 2** | | | | | |
| S1 | 58 | Male | Otolaryngology | PhD | Senior |
| S2 | 54 | Male | Otolaryngology | PhD | Senior |
| S3 | 40 | Male | Otolaryngology | PhD | Intermediate |
| S4 | 39 | Male | Otolaryngology | PhD | Intermediate |
| S5 | 52 | Female | Otolaryngology | PhD | Senior |
| S6 | 49 | Male | Otolaryngology | PhD | Senior |
| S7 | 61 | Male | Otolaryngology | PhD | Senior |
| S8 | 54 | Female | Otolaryngology | PhD | Intermediate |
| S9 | 49 | Female | Neurology | PhD | Senior |
| S10 | 35 | Male | Software engineer | Master | NA |
| S11 | 29 | Male | Software engineer | Bachelor | NA |

Note: S is short for specialist.

#### 2.2.1.2 Expected benefits and potential concerns of the App

Firstly, expected benefits and potential concerns for the implementation of mHealth App in the care for patients with chronic vestibular syndrome were discussed, which served as the basis of function determination and module design. Totally, three aspects of benefits and two aspects of concerns were obtained, including nine specific items, which is shown in Table 4 and explained in the following.

Table 4 Expected benefits and potential concerns of the App for CVS patients

| Categories | Expected benefits | Potential concerns |
|---|---|---|
| **Themes** | **Enhancing the illness perception** | **The burden of chronic App-use** |
| | **Enabling patient self-management** | Aggravating symptoms |
| | Visualizing disease variability | Low acceptability among the elderly |
| | Personalized VRT | **Legal and organizational aspects** |

| | |
|---|---|
| **Improving medical efficiency** | Privacy concerns |
| Popularizing vestibular rehabilitation | Responsibility distinction |
| Efficiency of communication | Sustainability |

**Expected benefits**

1) Enhancing the illness perception

The specialists in the vestibular field indicated that the mHealth application would augment the illness perception of patients and their caregivers. The current understanding of chronic vestibular syndrome among the public is quite limited, even among doctors in some primary hospitals. Many patients experiencing symptoms such as dizziness or tinnitus do not recognize themselves as being ill, leading to a lack of proactive medical measures. Additionally, there is insufficient societal awareness regarding the common symptom of dizziness, and there is a lack of an accessible popular science channel. There exists a profound gap between cutting-edge research and public knowledge.

*"The concept of the vestibular system sounds sophisticated; many individuals not even be aware that it resides within our ears. Despite its small size, it plays a crucial role and significantly influences our quality of life. When vestibular function is impaired, it can lead to a range of physiological and psychological symptoms in patients. Therefore, there is an urgent need for widespread public awareness and education about this organ and its associated disorders. I believe that mobile applications can serve as an excellent channel for disseminating information in this regard." (S5, Group 1).*

2) Enabling patient self-management

Due to the widespread use of mobile applications among the majority of patients, it has become feasible to documenting the occurrence of symptoms on each occasion and visualizing the variability of their disease, which will be a basis for self-management.

*"Many patients may forget when they experienced dizziness, how long it lasted, the triggering factors and accompanying symptoms. However, these details are crucial for the patients. Mobile applications can assist them in promptly recording and analysing variability of symptoms, enhancing their understanding of their disease conditions. This is particularly important for the self-management of patients and their caregiver." (S11, Group 2).*

What’s more, vestibular rehabilitation therapy can be automatic provided in mobile application, which could assist patients exercises in the home by themselves.

*“In the field of vestibular rehabilitation, there is currently a shortage of therapists, making it challenging to manage and cater to the vast patient population. Mobile applications can offer vestibular rehabilitation programs and guidance to patients, enabling them to achieve self-management in their homes.” (S7, Group 2).*

3) Improving medical efficiency

Specialists indicated that the mobile application can serve as a crucial avenue for popularizing vestibular rehabilitation. Utilizing the App to do the exercises can alleviate the burden on healthcare professionals to a certain extent. Simultaneously, the mobile App can offer guidance on various exercises methods, thereby contributing to an enhancement in medical efficiency.

*“In outpatient consultations, if you inform patients that they require vestibular rehabilitation, it necessitates a considerable amount of time to elucidate what it entails, how it is performed, and the duration of the treatment. However, utilizing applications can assist healthcare professionals in conveying this information to patients, thereby significantly saving time.” (S1, Group 1).*

Also, the mHealth application facilitates online communication between doctors and patients, and even enables mutual communication among patients. Given the difficulty of scheduling appointments for outpatient services in many hospitals, online consultation can contribute to the saving of certain healthcare resources.

*“The App can provide an online communication platform, avoiding the cumbersome process of scheduling appointments. Some less urgent issues can be resolved through online consultations.” (S5, Group 1).*

**Potential concerns**

1) The burden of chronic App-use

Specialists shown that the long-term use of mobile applications is not feasible due to the limitations imposed by their dizziness symptoms on their activities. Furthermore, specialists noticed that the unpredictable nature of symptom onset leads to heightened anxiety in many individuals. Frequent utilization of mobile phones to document and assess their symptoms may exacerbate the negative effects of the illness.

*"Although mHealth Apps can bring about numerous benefits, it is inevitable that prolonged use of smartphones itself may have an impact on the symptoms of patients with chronic foreground syndrome. Therefore, it is crucial to balance this aspect in the design of the App." (S9, Group 2).*

What's more, the majority of patients are middle-aged and elderly individuals who may resist using unfamiliar mobile applications. This resistance can adversely affect the promotion and utilization of the App. Additionally, despite the widespread prevalence of smartphones, it should be noted that some elderly individuals have limited proficiency in using smartphones, possibly restricted to basic functions such as phone calls or WeChat. Consequently, this condition may result in the exclusion of a subset of individuals who genuinely need the App.

*"One characteristic of chronic vestibular syndrome is relatively advanced age. There are some design challenges for applications targeting this demographic. Without considering the level of acceptance among the elderly, it is difficult for the App to demonstrate its benefits effectively." (S2, Group 2).*

2) Legal and organizational aspects

While previous experiences shown that the majority of patients were willing to share their personal data in the medical activities, specialists were particularly concerned about the security of patients' health information.

*"Maybe some patients would be afraid their data would become available to insurers or advertisers. These patients might fear certain consequences." (S3, Group 1).*

Some specialists expressed concerns regarding the potential impact of an mHealth application on the volume of patient, anticipating a notable surge that could consequently amplify the online workload for healthcare professionals. Notably, these additional responsibilities were perceived as particularly challenging, given that there is a lack of clear division of these additional responsibilities for healthcare professionals and the current remuneration system does not account for such activities, which could affect the sustainability of this App use.

*"We need to devise a solution involving the assignment of dedicated personnel for online medical activities or the adjustment of remuneration based on the online work to address the increased workload imposed on healthcare professionals by mHealth applications." (S2, Group 1).*

2.2.1.3 Desired functions and modules

Desired functions and modules for the mHealth applications for patients with chronic vestibular syndrome were discussed and identified during the focus groups. In the end, 8 modules were identified, including 20 specific functions in total, which is shown in Table 5. There were also many suggestions and thoughts generated in focus groups about the function design, which were explained in the following.

Table 5 Desired functions and modules of the app for patients with CVS

| **Modules** | **Functions** |
|---|---|
| The home page | Recommended reading |
| | Access points for other modules |
| Vertigo log | Record the symptoms |
| | Visualizing disease variability |
| Vestibular rehabilitation training | Instructions of VRT |
| | Detailed assessment of vestibular function |
| | Generate a personalized training plan |
| Dissemination of vertigo knowledge | Popular science article |
| | Medication Guidance |
| | Physician public lecture |
| | Disease managements |
| Physician consultation | Consultation online |
| Community notes | Post notes |
| | Give a like, comment |
| | Share and communicate |
| Make an appointment | Outpatient appointment |
| Personal center | Personal profile |
| | Appointment and training records |
| | My notes |
| | Submit suggestions |

1) The Home Page

Specialists asserted that the home page is a crucial component of an App, significantly influencing users' preferences and perceptions of the App. Specifically, the home page should include some recommended reading and access points for other modules.

"*The homepage can offer curated content recommendations, aligning with prevalent design principles in contemporary mobile applications.*" *(S9, Group 1).* "*Given that our App primarily targets patients, it is advisable to prominently display essential features on the homepage to facilitate easy access and utilization for users.*" *(S6, Group 2).*

2) Vertigo Log

Specialists unanimously agreed that the vertigo log module would become a highlight of this App. Documenting the occurrence of symptoms on each occasion and visualizing the variability of their disease has significance for diagnosis and management of patients.

*"The vertigo log should furnish a prompt interface for the addition of new records, accompanied by a graphical representation of fluctuation trends. This assists patients in gaining a visual understanding of the evolution of their condition." (S4, Group 2). "If patients record their symptom episodes, it can be used when they go to see the doctor and assist doctors to make decisions, because symptoms characteristic is one of the diagnosis indicators." (S8, Group 2).*

3) Vestibular Rehabilitation Training

Experts asserted that vestibular rehabilitation is the foremost function of this App, serving as the primary motivation for its development. However, it was acknowledged that this module was also the most challenging, with specialists deeming it to require the most time investment in the development process.

*"Before providing the rehabilitation program, a serious of assessment are needed to generate a personalized training plan." (S1, Group 1). "During the vestibular rehabilitation, introductions and teaching videos should be provided, because words cannot explain accurately sometimes." (S3, Group 1). "It would be better if this App gives some feedback or awards after rehabilitation every time." (S8, Group 2).*

4) Dissemination of vertigo knowledge

Knowledge of vertigo is multifaceted, encompassing areas such as popular science, medication guidance, lifestyle management, and more. Specialists acknowledged the initial challenges in achieving comprehensive coverage but anticipated ongoing updates in subsequent content.

*"The dissemination of knowledge about vertigo disorders is imperative, but our current efforts are insufficient. We aspire that a mobile application can serve as an enhanced platform for us. Subsequently, we envision collaborative efforts in generating educational material to further augment influence." (S2, Group 2). "What's more, the popularization of medical knowledge constitutes a critical function in mobile health Apps. However, collaboration with hospitals is of utmost importance in ensuring the scientific integrity of content. Users are most apprehensive about encountering non-authoritative content, posing a significant detriment to the viability of a mHealth App." (S10, Group2)*

5) Physician consultation

Specialists perceived the design of this sector as intricate, given that the majority of mobile health Apps in current market were profit-driven, resulting in a limited pool of reference samples. Following expert discussions, it has been suggested that a points-based system could be employed, establishing a certain threshold without imposing additional charges.

*"Being able to consult doctors or rehabilitation therapists online is highly essential for patients in more remote areas. It is also crucial for patients in first-tier cities such as Beijing or Shanghai, as offline follow-ups consume a significant amount of time. In cases where the medical condition is stable, such kind of follow-ups are unnecessary." （S3, Group 2）. "Recognizing that free consultations are inconsistent with market norms and, but hospitals lack explicit fee regulations, some discussions are needed to address this complexity." (S6, Group 1).*

6) Community notes

As a consensus，the community served as a crucial module for enhancing user engagement. When users could readily access the content they like and engage in effective communication, they were more inclined to invest time in the application.

*"Users are permitted to post content; however, a certain level of scrutiny is required. Given the medical nature of our application, it is imperative to avoid any misleading or inaccurate*

*information." (S4, Group 1). "Give a like and comment is the basic function of an App. Also, share can attract some potential users, which is needed to be included." (S8, Group 2).*

7) Make an appointment

Specialists thought that the appointment function could be integrated with WeChat Mini Programs, directly connecting to the hospital's existing appointment system. This approach would not only enhance patient convenience but also mitigate the burden on the hospital. However, it would lead a lot of privacy and data security issues, which need to be considered carefully.

*"On a technical level, executing this is not particularly challenging. However, it necessitates compliance with privacy regulations." (S4, Group 1). "Integrating with hospital systems requires a meticulous process of reporting and approval, presenting a considerable challenge." (S5, Group 2)*

8) Personal Center

Specialists pointed out that the design of a personal center could also draw inspiration from numerous applications currently prevalent in the market, basically including personal information, appointment and training records, my notes and a place to submit suggestions.

*"In the layout of the personal center, it is imperative to put the vestibular rehabilitation plan and records on a prominently position, along with appointment records" (S10, Group 2). "The personal center should enable users to provide feedback or suggestions for the App. Given that this app is firstly developed for the CVS demographic, there may be aspects that have not been comprehensively considered." (S3, Group 1)*

### 4.2.2 Development of application prototype

#### 2.2.2.1 The whole picture of this App

According to the results of focus group, development of application prototype was conducted during the period from January to June 2023, encompassing both design and coding. The researcher was responsible for content creation, interface design and oversight, and the researcher was cooperated with software development team in code writing and testing. User interface (UI) design was accomplished using Axure RP 10 software, and server technology adhering to the Java 2 Platform Enterprise Edition (J2EE) specifications was employed for the backend development of this App. During the development phase, researchers and software development team convened regularly on a weekly basis, assessing the progress of the development and scrutinizing its milestone achievements.

The highlights of this application encompass the vertigo log and vestibular rehabilitation training, constituting the most time-consuming segments during the developmental phase. Researchers identified the symptoms characteristic that necessitated documentation and vestibular functions needed to be assess drawing on existing literature and clinical experiences. Also, a series of instructional videos on vestibular rehabilitation exercises were meticulously filmed in accordance with guidelines[107]. Finally, after the interface design and content creation, the process of coding and testing spanned a duration of two months, ultimately yielding a prototype for the application.

2.2.2.2 The home page

In this module, users can have an overview of all the functions. And recommended reading materials are dynamically showcased on the homepage, which is shown in figure 4.

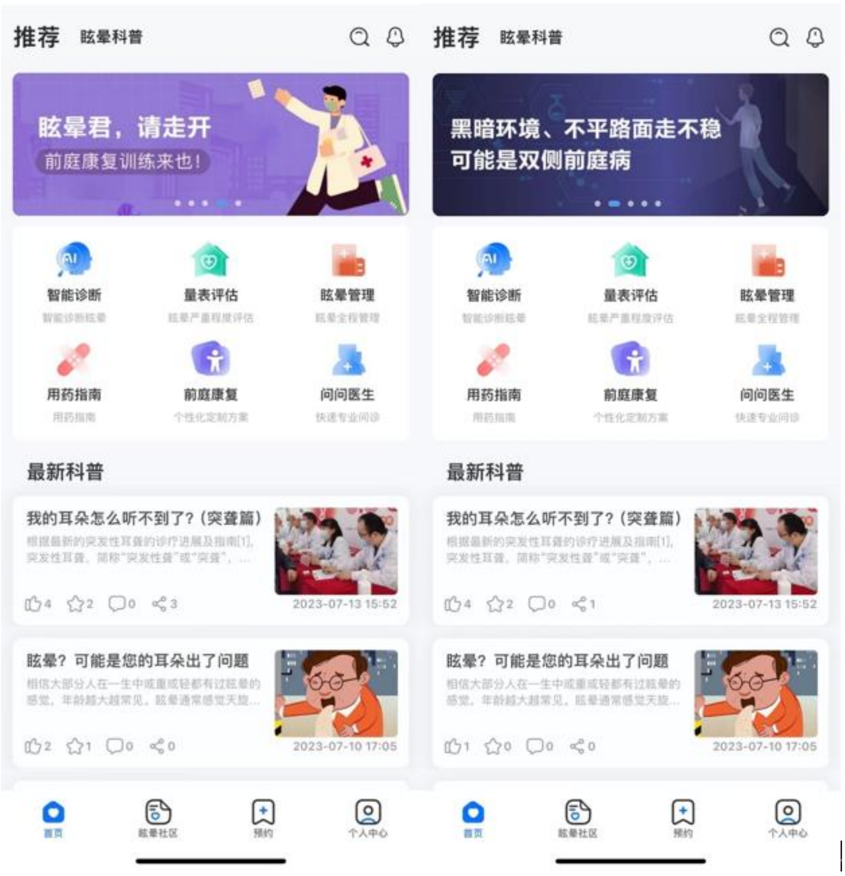



Figure 2 The home page module

### 2.2.2.3 Vertigo log

In this module, users can add their own detailed vertigo log by filling in the general information, the onset and severity of symptoms, etc., as the basis for subsequent, which is shown in figure 5.

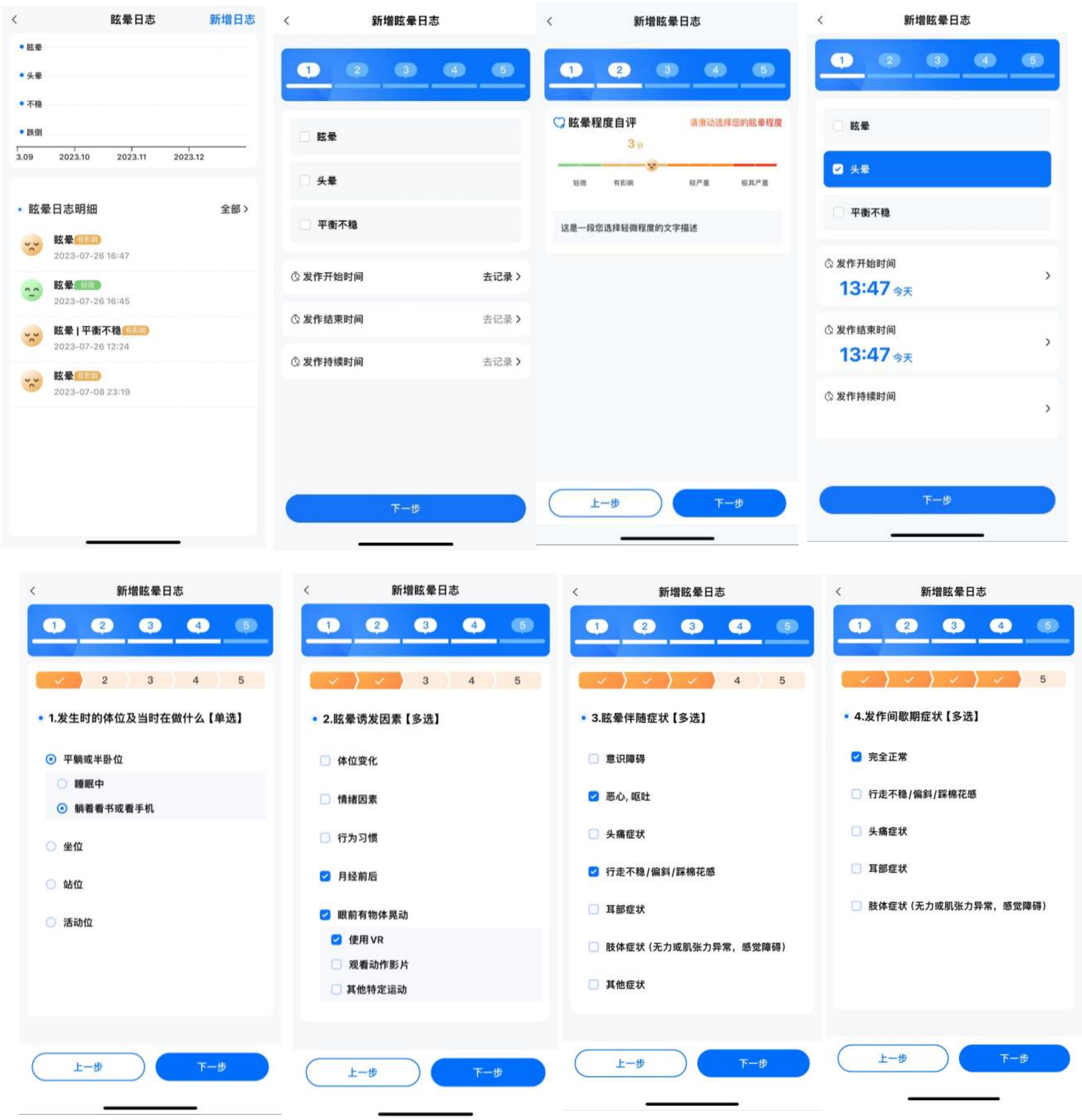
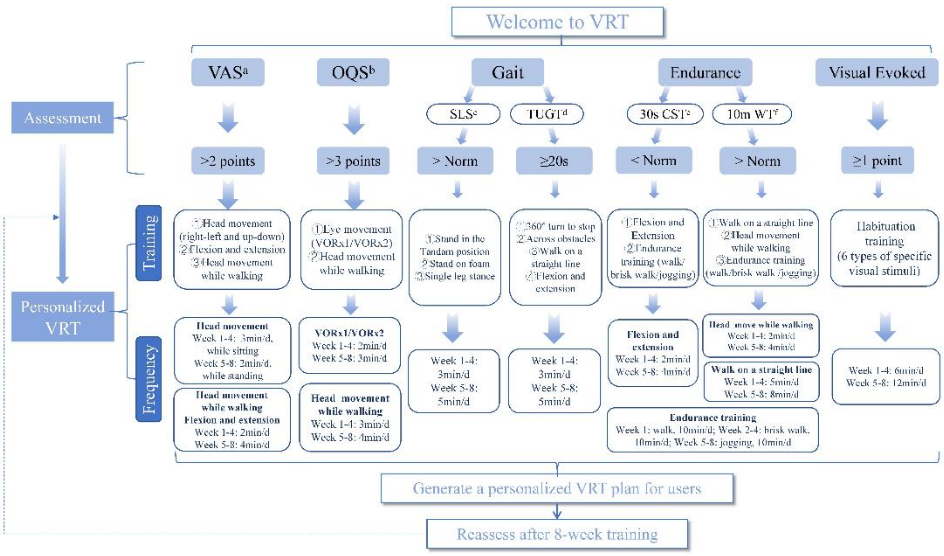



Figure 3 Vertigo log module

### 2.2.2.4 Vestibular rehabilitation training

In this section, users will see the instructions of vestibular rehabilitation first. Also, because vestibular rehabilitation programs vary from person to person, so, a detailed data collection module has been designed to ensure that the most beneficial program to the user can be presented. Users will be asked to fill in a questionnaire of vestibular function, and complete some balance tests, then the system will generate a personalized rehabilitation plan. Vestibular function assessment and personalized rehabilitation programs generation in this app are shown in Figure 6 in detail.

Users can complete the daily training plan and weekly training plan according to the content of the rehabilitation, until completing the whole rehabilitation program, which is shown in figure 7.




| Single Leg Stance Test Norm | | |
|---|---|---|
| Age | With eyes open (s) | With eyes closed (s) |
| 20-49 | 28.8 | 20.7 |
| 50-59 | 24.2 | 6.1 |
| 60-69 | 27.1 | 2.0 |
| > 70 | 18.2 | 1.0 |

| 30-Second Chair Stand Test Norm | | |
|---|---|---|
| Age | Man | Woman |
| 60-64 | 14 | 12 |
| 65-69 | 12 | 11 |
| 70-74 | 12 | 10 |
| 75-79 | 11 | 10 |
| 80-84 | 10 | 9 |
| 85-89 | 8 | 8 |
| 90-94 | 7 | 4 |

| 10-Meter Walk Test Norm | |
|---|---|
| Age (unisex) | Time (s) |
| 20-29 | 7.5 |
| 30-39 | 7.5 |
| 40-49 | 7.2 |
| 50-59 | 7.6 |
| 60-69 | 8.1 |
| 70-79 | 8.9 |
| 80-99 | 10.4 |

*Note: aVAS: Visual Analogue Scale; cSLS: Single Leg Stance; dTUGT: Timed Up and Go Test; e30s CST: 30-Second Chair Stand Test; f10m WT: 10-Meter Walk Test.*

Figure 4 Vestibular function assessment and personalized rehabilitation programs generation


Figure 5 Vestibular rehabilitation training module

### 2.2.2.5 Dissemination of vertigo knowledge

This part includes a large number of popular sciences uploaded by professionals, physician public lectures, clinical guidelines interpretation and so on. Users can subscribe to their favorite topics and search for content they are interest in, which is shown in figure 8.

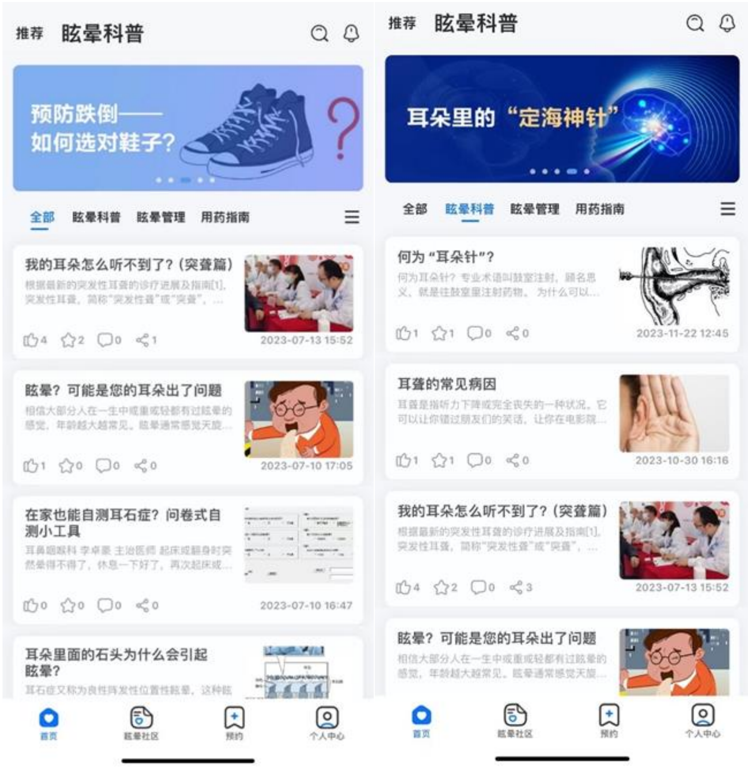



Figure 6 Dissemination of vertigo knowledge module

2.2.2.6 Physician consultation

In this module, users can communicate with their primary physician and ask any doctor they are interested in. Their questions about illness or rehabilitation can be answered here, which is shown in figure 9.


Figure 7 Physician consultation module

### 2.2.2.7 Community notes

This module is a vertigo community where users can post their notes and see all public notes posted by others and give a like or comment on them. In this module, patients can share their experiences and also find inspiration from others' sharing, which is shown in figure 10. Through this kind of community interaction, the compliance of patients can be improved to a certain extent.


Figure 8 Community notes module

### 2.2.2.8 Make an appointment

In this section, users can make an appointment to see a doctor at the hospital and view their examination records online, which is shown in figure 11.


Figure 9 Make an appointment module

2.2.2.9 Personal centre

The final module is the User centre, which like other Apps, includes patients' personal profiles, appointments and training records, as well as notes that user bookmark and like, which is shown in figure 12. And they can also submit feedbacks and suggestions for this App, which could help developers to make it better.


Figure 10  Personal centre module

## 4.3 Discussion

This section illuminated expected benefits and potential concerns regarding the implementation of mHealth App for CVS patients, then determined the App modules and functions. Subsequently, an App prototype was developed, which will improve the accessibility of vestibular rehabilitation, and also assist patients and healthcare professionals in symptom management.

Experts unanimously believed that a reliable mHealth application developed by hospitals has significant benefits for patients with chronic vestibular syndrome, especially for the patient self-management and higher medical efficacy. However, there are also some potential issues that need to be considered.

Firstly, they expressed concern that asking patients to frequently rate and record their symptoms with an mHealth application could facilitate negative aspects of illness behavior. Previous studies has also shown that vertigo patients paying excessive attention to their symptoms might aggravate the disease’s impact on their daily lives[111]. And studies of patients with vertigo also found that long-term disability depends more on psychological than physical factors[112]. Therefore, to prevent aggravating the disease’s impact on users, we have endeavored to streamline both the content and functionality design, aiming to minimize the user burden and to avoid employing terminologies of elevated severity when describing symptoms. Additionally, during the subsequent utilization of the App, it is imperative to dynamically monitor the patient's usage patterns to ensure that the benefits outweigh the drawbacks.

In addition, this study highlighted significant concerns related to data privacy and the accessibility of patient information, reflecting a current trend in healthcare. One of the major challenges faced by the global healthcare system in recent years is the need to identify safe and effective health apps that benefit both practitioners and patients[113]. There is a growing necessity for regulations, particularly for apps that are used for diagnosing, treating, or managing chronic or high-risk conditions[8]. The European Institute for Standardization has advocated for the development of such regulatory frameworks by all nations[114]. Although these frameworks are not intended to replace market-based evaluation systems (such as app ratings in the Apple Store), they are expected to complement these systems and provide valuable guidance in this area.

When considering the modules and functions of this App, the first highlight was the vertigo log due to its peculiar significance for patients with CVS. Previous studies[115] and clinical experience have shown that the symptom characteristics, regarding the timing (onset, duration, and evolution of dizziness), triggers (actions, movements, or situations), simultaneous phenomenon and so on, were essential for diagnosis and determining whether the etiology was peripheral or central, which could guide the further treatment and management. For example, episodic vertigo triggered by head motion may be due to benign paroxysmal positional vertigo (BPPV)[116], while vertigo with unilateral hearing loss suggests Meniere's disease (MD)[117]. Therefore, the vertigo log module was designed in this App to assist diagnosis and further treatment as well as management.

The other focus of this App was vestibular rehabilitation. The effect of VRT on patients with CVS has been proved by numerous previous research[33, 118], while its adherence and accessibility were still low in current years and reported to be below 50%[119]. In addition, geographical and financial constraints pose significant barriers to hinder the accessibility of vestibular rehabilitation services. Therefore, current studies focus on the telehealth solutions, such as online consultations and remote monitoring, which has emerged as promising strategies to overcome these geographical and economic barriers, ensuring that individuals can access rehabilitation services if they need. Linda et.al[120] developed a "Vestibular App" with gaming elements. A VR based vestibular rehabilitation was also effective in reducing vestibular symptoms in a recent randomized controlled trial[83]. However, there was still not a mobile App or platform in this field that has been widely accepted and used in clinical. Therefore, this study innovated the use of mobile App as a tool for personalized vestibular rehabilitation in the hope of promoting VRT and improving patient accessibility in China.

In sum, an App prototype was designed and developed in this phase for patients with CVS, which was optimized in the following research, based on the user experiences.

# 5 Acquisition of user experience

## 5.1 Research methods

### 5.1.1 Study design

Qualitative descriptive study was employed in this section, which is based on the naturalistic inquiry[121]. Its principle is to recognize the common experience of human communication, diversity and interaction, and close interaction separable essence. It's the method of first choice when straight descriptions of phenomena are desired[122].

Therefore, this research used a descriptive qualitative design to reveal users' experience and perceptions of this App, which was designed and developed for CVS patients.

### 5.1.2 Research participants

The researcher used the maximum variation sampling[121] to select the participants. This sampling method could enhance the external validity and generalizability of the research's findings by including participants with diverse backgrounds, demographics, or characteristics,

In addition, given that some patients may find it difficult to use mobile phones for an extended period due to dizziness or unsteadiness, yet they still require mobile medical services. Therefore, this study also interviewed the main caregivers of patients, which could assist patients in using the App to complete rehabilitation training or symptom management.

Inclusion criteria for patients or their main caregivers:

1) People who are diagnosed with chronic vestibular syndrome or a family member of someone with chronic vestibular syndrome;

2) Patients who have been recommended for vestibular rehabilitation;

3) Over 18 years old;

4) Have normal communication and literacy skills.

Based on data saturation, the final sample size was 9. Saturation was reached when no new themes, insights, or information emerged from further data collection or analysis, indicating that enough data had been gathered to fully address the research questions.

### 5.1.3 Research tools

3.1.3.1 Research tool

Descriptive qualitative research employs the researcher herself as the research tool[123].

The researcher is currently pursuing a Master's degree in Nursing with a specialization in Health Informatics and possess a profound understanding of the design and development of mobile health applications. Additionally, the researcher has undertaken an internship at a specialized Otolaryngology hospital, gaining familiarity with patients suffering from chronic vestibular syndrome and establishing a trustworthy relationship with the research subjects. Furthermore, during the academic tenure, the researcher received systematic training in qualitative research methodology, covering research paradigms, data collection, analysis methods and so on. Moreover, the researcher's undergraduate thesis also employed qualitative research methods and has practical experience in conducting interviews, which contributed to the smooth execution of this study.

3.1.3.2 Interview tools

1) General Information Questionnaire (Appendix 2: developed by the researcher, which was mainly used to investigate the basic personal information of the interviewees, such as age, education level, medical insurance, average monthly family income, and main caregivers.

2) Interview outlines (Appendix 3): based on the research question and objective of this section, the preliminary interview outline was designed according to the relevant literature, and the formal interview outline was adjusted after 2 pre-interviews were completed and expert advice was consulted. The interview outlines primarily revolved around users' experiences and perspectives, consisting of open-ended questions, as detailed in the appendix.

### 5.1.4 Data collection

In August 2023, patients with chronic vestibular syndrome or their main caregivers of Vertigo and Balance Centre in Eye & ENT Hospital of Fudan University were selected as the interviewees.

Before the interview, the researcher explained the purpose, process and significance of the research to the research subjects. Researchers confirmed that personal data of participants would not appear in any means and would be replace with anonymous numbers. After the consent of the participants, they asked to sign the informed consent (Appendix 4. The interviews were held in a quite conference room at the Fudan University Hospital.

After a brief welcome and self-introduction, the researcher firstly presented the App prototype to the interviewees, introducing its functions and usage methods, then, participants were asked to try this App by themselves. Following thorough interaction with the App by the participants, the formal interview commenced. The researcher conducted the interview according to the interview outline. The interviews were recorded in full. At the same time, the researcher observed the facial expressions and body language of the participants, and made interview notes carefully. The interview was terminated when no new information emerged from the participant's statement. Each interview lasted for 25-45 minutes and interviews were recorded with a voice recorder. After the interviews, participants were asked to fill out a general information questionnaire. Finally, the researcher and interviewees mutually added each other as contacts on the WeChat for member checking and feedback on the research findings.

### 5.1.5 Data analysis

Data collection and analysis were carried out simultaneously in this study. After an interview, the researcher transcribed it into word manuscript within 24 hours, and the transcription should reflect the sentence pauses, voice expression, facial expression and body language of the subjects at that time. After the transcription, the participants read the written manuscript to make sure it was right.

The general information of the interviewees was sorted out using Microsoft Excel. The demographic data of the participants were described using frequency, component ratio, mean, and standard deviation.

Interview data were analyzed using conventional content analysis method[110], which could gain direct information from study participants without imposing preconceived categories or theoretical perspectives. It's usually used in studies that focus on exploring a phenomenon when the existence of theoretical literature or research on the phenomenon is limited[110]. Data analysis started with reading all data repeatedly to achieve immersion and obtain a sense of the whole. Then, data were read word by word to derive codes. Codes then were sorted into categories based on how different codes were related and linked. These emergent categories were used to organize and group codes into meaningful clusters. Next, definitions for each category, subcategory, and code were developed[124].

### 5.1.6 Ethical considerations

At any time, The interview data were all named by numbers, only the research team had access to the interview recordings and written materials, and the personal information of the interviewees would not be disclosed in any form. Before the interview, participants were asked to sign an informed consent form and they were informed that they could decline to answer the questions or withdraw from the study at any time. Before the study, The Institute of ethical review board of Eye and ENT Hospital of Fudan University approved this study (reference No. 2019091).

### 5.1.7 Quality control

1) Before the study, the researcher received systematic training in qualitative research methodology, covering research paradigms, data collection, analysis methods and so on, to ensure rigor in the study process.

2) Before the study, researchers have read relevant literature in detail and consulted experts in related fields to ensure that the interview outline and research plan formulated were scientific and applicable.

3) During the interview, the researcher didn't stick to the interview outline, but paid more attention to the actual situation of the interviewees, and asked questions flexibly to ensure that the true thoughts of the interviewees can be dug out.

### 5.1.8 Reliability

In addition to the above, the researcher used following strategies to ensure that findings were as credible and trustworthy as possible.

#### 3.1.8.1 Peer debriefing

Peer debriefing refers to a peer familiar with the research or the phenomenon involved should review the data, decision matrixes, and other documentation to question the methods and interpretations[125]. Peer review should be ongoing throughout the research to ensure credibility and avoid problems that would be difficult to correct at later points in the study[126].

In this study, researcher regularly engaged in topic discussions with supervisor and members of the supervisor committee. The discussions primarily focused on the rationality of the coding, the research theme, and other relevant considerations. Subsequent to each discussion, comprehensive records were maintained, then corresponding suggestions were incorporated into the research to enhance its quality and reliability.

3.1.8.2 Member checking

The member check, whereby data, analytic categories, interpretations, and conclusions are tested with members of those stake-holding groups from whom the data were originally collected, is the most crucial technique for establishing credibility[127].

This research involved the participation of three members to validate the research findings. Communication with all three participants was conducted through WeChat, wherein the researcher transmitted the finalized themes in tabular format. A one-day period was allocated for the participants to verify the results. During the WeChat audio communication, all three participants expressed that the research findings adequately aligned with their usage experiences of the App, indicating their belief in the authenticity and reliability of the study results.

## 5.2 Research results

### 5.2.1 Demographic data

A total of 9 participants were interviewed in this part, including patients or their main caregiver. The general information of respondents is shown in Table 6.

Table 6 User information form (N=9)

| Serial Number | Category | Gender | Age | Marriage | Disease Duration |
|---|---|---|---|---|---|
| P1 | Patient | Female | 47 | Married | 2 |
| P2 | Patient | Female | 45 | Married | 6 |
| P3 | Caregiver | Male | 29 | Unmarried | NA |
| P4 | Patient | Female | 38 | Married | 5 |
| P5 | Patient | Female | 35 | Unmarried | 3 |
| P6 | Patient | Female | 41 | Married | 4 |

| | | | | | |
|---|---|---|---|---|---|
| P7 | Patient | Male | 27 | Unmarried | 2 |
| P8 | Patient | Female | 25 | Unmarried | 2 |
| P9 | Caregiver | Female | 31 | Married | NA |

### 5.2.2 Interviews results

Conventional content analysis yielded 3 themes and 15 sub-themes in this study, all of which were defined in Table 7.

"Perceived usefulness" contained Reduce healthcare costs, Enhance self-efficacy, Provide comprehensive service, Facilitate communication. "Potential impediment to usability" were embodied in the overspecialized content, complex pattens, long-term usage and technological anxiety. Users' requirements for optimization of this App embodied in the third theme, including larger text display, more understandable language, user-friendly patterns, appropriate voice prompts, rehabilitation exercises time-reminder, appointment register and follow-up visit instruction, more attention to psychological condition.

Table 7 Interviews results

| **Themes** | **Sub-themes** |
|---|---|
| Perceived usefulness | Reduce healthcare costs |
| | Enhance self-efficacy |
| | Provide comprehensive service |
| | Facilitate communication |
| Potential impediment to usability | Overspecialized content |
| | Complex pattens |
| | Long-term usage |
| | Technological anxiety |
| Optimization requirements | Larger text display |
| | More understandable language |
| | User-friendly patterns |
| | Appropriate voice prompts |
| | Rehabilitation exercises time-reminder |
| | Appointment register and follow-up visit instruction |

| | |
|---|---|
| | More attention to psychological condition |

3.2.2.1 Theme 1: Perceived usefulness

Perceived usefulness is the subjective evaluation or belief held by an individual regarding the extent to which a particular technology, system, product, or service is likely to enhance their performance, efficiency, or overall effectiveness in achieving specific goals or tasks[128]. There were four items under this theme, including reduce healthcare costs, enhance self-efficacy, comprehensive functionality and strong reliability.

1) Reduce healthcare costs

Participants generally believed that this application could reduce healthcare costs, including both economic and time costs. Economic costs mainly included transportation expenses, unnecessary medication costs, and losses caused by the inability to work.

P1 said: "*Since I got this illness, I have to come to the hospital for treatment every month. Taking medicine all the time is not good, and I've spent a lot of money. However, I can't go to work, and I'm almost depressed. If I can communicate with the doctor using this App and recover at home, it would save a lot of money.*"

In addition to the economic costs, more people expressed a reduction in the time cost.

P3 described the following "*Now it's too difficult to make a hospital appointment. We have to set an alarm to quickly register in order to see a doctor at the hospital. If we have remote medical consultations through this App, we won't have to keep going in person all the time.*"

Especially for patients in underdeveloped areas with limited medical resources, the reduction in healthcare costs is more noticeable.

P6: "*Before we had to rush to Shanghai from our hometown every month for medical treatment, which created a significant burden. Moreover, we were not familiar with this rehabilitation training before. If we can complete the training through the App in the future, I won't have to come to Shanghai all the time.*"

2) Enhance self-efficacy

Patients with chronic vestibular syndrome generally lacked relevant medical knowledge, had a low awareness of the disease and exhibited poor adherence to treatment and rehabilitation, which could negatively impact patients' confidence in rehabilitation treatment and affect the effectiveness of rehabilitation, resulting in low self-efficacy[129]. However, interview results indicated that users believed this App can address these issues to some extent.

P2: "*My doctor had also suggested me to do rehabilitation exercises, but I often forgot it at home, especially when my symptoms improved. With this App now, it can remind me to train regularly, so I could recover better.*"

P5: "*Since I fell ill, I've often been searching online for information about this disease. However, it's difficult to distinguish the truth from falsehood online, and there are many scammers advertising fake remedies. This App, developed by a hospital, is very reliable. Therefore, I can learn a lot about diseases and it helps me better cope with my illness.*"

3) Provide comprehensive service

The main functions of this App were vertigo log and vestibular rehabilitation. In addition, there were also services such as vertigo community, communicate with doctors, knowledge of vertigo, etc. This App was comprehensive and free, almost catering to users' all needs for disease management.

Some users believed that the vertigo log was the most essential function for them, as it can prevent forgetfulness.

P7 indicated that: "*When I go for a follow-up appointment, the doctor always asks me about recent symptoms, the duration of vertigo, specific characteristics of the symptoms, and what might be causing them. However, I often forget these details. If this App could record these comprehensively, I wouldn't have to worry about this issue anymore, and it would also make it easier for the doctor.*"

Others thought that the vestibular rehabilitation module was what they need most.

P8: "*I know vestibular rehabilitation is beneficial for my condition, but I don't know how to do it. The doctor previously showed me some exercises, but I didn't perform them well. If I use this App, I can learn how to do them better.*"

4) Facilitate communication

Users communicate with other patients using this App, which could share experiences and increase their confidence in facing the disease. They can also communicate with doctors online, rather than tough offline appointments.

P4 indicated that peer communication was important for people with chronic conditions: "*I joined some WeChat groups for patients before, but there were some people selling medications or insurance in the groups, so I can't believe it and dare not chat in the group. It would be great if this App allows communication among patients. I hope the hospital can manage users and remove all the scammers.*"

Some user also believed that communicating with doctors online could help them a lot.

P9: "*Registering at the hospital is really difficult. If it were possible to have follow-up appointments through an App, it would be very convenient. Even if there were charges for the service, it would be acceptable, as it would at least eliminate the need to wait for a month to see a doctor.*"

3.2.2.2 Theme 2: Potential impediment to usability

Impediment to usability means any factor, obstacle, or condition that hinders or obstructs the ease, effectiveness, or convenience with which a system, product, or service can be used by individuals. It denotes anything that interferes with the overall user experience and makes it more challenging for users to interact with and benefit from a particular entity or functionality. Totally, there were four aspects of impediment to usability of this App, including too specialized content, complex pattens, long-term usage and technological anxiety.

1) Overspecialized content

Some users expressed that certain vertigo-related knowledge presented in this App was too professional and difficult to understand, which could impede the usage.

P6 said: "*Because it is an App developed by the hospital, the content is undoubtedly scientific and reliable. However, for ordinary people, some of the content is too specialized. Although they are eager to learn disease knowledge, they maybe not understand some of it, which can affect people's experience.*"

A user provided specific explanations about the content which was found difficult to understand.

P8 said: *“I feel that the recommendation content on the homepage is quite good, very interesting, and includes some pictures and videos. However, the medication guide section is not well-done; there is a lot of content, but it lacks interface design, with only a white background and black text. Additionally, many medication terms are not understood, and there are no corresponding explanations.*”

2) Complex pattens

The user expressed that somethings in the App were too complicated. They only needed basic functionality, not something that looked interesting but wasn't practical.

P6 was negative about current integral mode: “*Why do we need credit to communicate with doctor? This feels very troublesome, I think it is even better to pay directly, I can accept paid consultation, but this credit is really troublesome.*”

3) Long-term usage

Long-term use of the App could impose a certain burden on patients, as it leads to continuous attention to their illness and symptoms, thereby increasing their anxiety and fear. Just like P3 said: “*Recording all the symptoms can be frightening, especially during periods when vertigo attacks are frequent.*”

Prolonged use of mobile phones is also not beneficial for patients' health.

P7: “*I often feel dizzy after looking at mobile phone, which makes me reluctant to use my phone for an extended period at home. Although this App is very convenient, it's not something I can use all the time.*”

4) Technological anxiety

For users, they both wanted to enjoy the convenience brought by technology and, at the same time, felt anxious about mobile technology, worrying that they may not be able to use this tool effectively.

P1: "*This App has so many interfaces and sections, and I'm afraid I won't be able to learn how to use it. I spent a long-time to learn WeChat before I use it, and I may not be able to use this App independently*."

Some users were concerned about the security and privacy issues brought by mobile technology.

P3: "*After collecting so much user health information, how can the App ensure that it will not leak? How can patient privacy be protected? Can only doctors access patient information?*"

3.2.2.3 Theme 3: Optimization requirements

Optimization requirements refers to the specific criteria or conditions that need to be met in order to enhance or improve the efficiency, performance, or effectiveness of a product, application or system. Optimization requirements outlined the desired outcomes and standards that should be achieved through the optimization process. In the end, 7 user requirements for App optimization were obtained in interviews.

1) Larger text display

The font is an important factor affecting the App usability. Two participants thought that larger text display could be better to use.

P1 indicated that "*It would be nice if the text display was a bit bigger, it looks a bit tired now, especially in the filling out of the questionnaire part. When a page has multiple questions that need to be answered, I may be looking at the wrong line*."

P3 also said "*Because my mother has a headache when she looks at her mobile phone for a long time, we hope that the App font will be larger, the page layout will be concise, and not too flashy.*"

2) More understandable language

Understandable language in a mobile health App was crucial for ensuring that users could comprehend the information presented to them. And this was one of the requirements mentioned most frequently by users in the interviews.

P2 said "*The scientificity and authority of popular science articles are very important and I hope they are absolutely right. But they should be easily understood by users. I know it's hard to do both, but I still think it's important. Like the medication guide, I'm a little confused.*"

P4 an P5 all mentioned that "*This App contains scientific content, but there are some parts that I find difficult to understand. I hope to avoid using medical terminology as much as possible.*"

3) User-friendly patterns

Many users hoped that this App had a simpler patten, instead of using complex features to attract users.

P2 indicated that "*I hope the operation pattern of the App is simple, because I don't need something interesting to attract me. Many patients like me use this App because its specialty, So, there is no need for complex patterns like other social Apps.*"

P6 was negative about the current integral mode "*Why do we need credit to communicate with doctor? This feels very troublesome, I think it is even better to pay directly, I can accept paid consultation, but this credit is really troublesome.*"

4) Appropriate voice prompts

Appropriate voice prompts can make rehabilitation training easier, especially for elderly patients. P3 and P4 said directly "*It might be better if there are some voice prompts*."

P5 also indicated that "*Can we have some voice prompts when filling out questionnaires and doing rehabilitation exercises? Sometimes it's not convenient to look at the screen while doing the action.*" But when researcher asked whether popular science articles need to be read aloud for users to listen and learn, most participants said no.

5) Rehabilitation exercises time-reminder

The scheduled reminders were very important because people may forget their rehabilitation training, even though it only took 20 minutes. It was also one of the most mentioned requirements.

P1 told that “*I think vestibular rehabilitation is very effective, but I forgot to do it for a long while. I hope there can be a reminder function, such as reminding me of the time for rehabilitation training on WeChat, otherwise I will forget*.”

When symptoms improved, patients were more likely to forget to do rehabilitation training. However, VRT required long-term perseverance.

Just like P5 said, “*I haven't done vestibular rehabilitation since I stopped feeling dizzy. Because when you don't have symptoms, you will forget to train. But I know vestibular rehabilitation is still needed for me, so I want to be reminded to complete training at a set time every day. I'm sure it's very important for most patients*.”

6) Appointment register and follow-up visit instruction

Patients are required to schedule appointments in advance to visit hospital, and prearrange appointments for examinations, often necessitating a waiting period of one to two months. Moreover, the lack of understanding of the consultation process results in the expenditure of considerable time and effort. So, they requested a specialized "auxiliary doctor" to assist them with appointments and follow-up visits.

P2: “*In addition to knowledge related to illnesses, I also hope someone can tell me some information about hospitals, such as how to make appointments, how to seek medical attention, and how examinations are conducted, etc.*”

7) More attention to psychological condition

Only one patient explicitly put forward this requirement, but most of them mentioned they had psychological distress after suffering illness.

P1 voluntarily said that “*Since my illness, I have not been able to work, but also let my son often accompany me to the doctor, I feel very guilty because I caused a burden to the family.*”

P4 directly mentioned that “*Can you provide some psychological counselling related services? To be honest, I am very anxious about vertigo. Or at least provide some information about mental health.*”

## 5.3 Discussion

The App prototype developed based on the specialists focus groups in the Chapter 2 exhibits comprehensive functionalities and considerable expertise. However, regarding to its specific design and user-friendliness, it remains really essential to consider user experiences and recommendations. Consequently, qualitative descriptive interviews were conducted in this section to gather perspectives from potential users of this App, followed by systematic summarization and analysis.

Firstly, interview results indicated that participants expressed relatively positive and affirmative evaluations regarding the "perceived usefulness" of this App. They acknowledged the App's constructive impact in reducing healthcare costs, enhancing self-efficacy, providing comprehensive service and facilitating communication. However, in terms of usability, there were several impediments, such as the presence of over-specialized content and intricate patterns. Therefore, the seven optimization requirements proposed by participants in the interviews were particularly crucial for enhancing the usability of this App.

Regrading to the optimization, the first points they proposed was font. Almost all potential users of this App have experienced vertigo. If a smaller font is used in pursuit of a beautiful interface, users may need to watch it for a longer time, which could cause extra vertigo or discomfort for them. In the pervious researches, user requirements for larger text display in the mHealth Apps were very common, especially in the elder population. Zhong et.al[130] designed a mobile phone-based gait assessment App for the elderly and in the satisfaction measuring phase, a larger font size was required by participants. Fang and Yang[131], who aimed to optimize elderly medication reminder mobile App, also got feedback from potential end users about larger text display. However, the App developed in this research was not only designed for elderly because patients with chronic vestibular syndrome have a wide age distribution, they can be affected at any stage from childhood to old age[132]. Therefore, whether it was really necessary to adjust the font of this App prototype required gathering more user opinions and conducting further quantitative analysis, which were shown in the next chapter.

Another concern was readability and understandability of health-related knowledge in this App. Recent years, substantial efforts to improve health literacy are still needed, and the vestibular disease field is also the same. Studies have shown that the amount of health information available to the public and the means with which one can access health information has increased substantially in info-age. However, this increase has made addressing health literacy a more difficult pursuit to some extent[133]. And one of the reason leading to this situation is readability and understandability of mHealth Apps[134]. There was a study focused on mHealth Apps for heart failure patients showed that the readability of most Apps is lower than expected[135], which limited their potential for improving patient outcomes. Although there is no similar research specifically focused on vestibular diseases, considering that the recognition of chronic vestibular syndrome in the population is relatively low, and the related medical terms are highly specialized, the readability and understandability of this App appear to be more important. Therefore, it was essential to optimize the content to make it more understandable.

There was also a focus on psychological issues. Previous studies found that the vast majority of vertigo patients suffer from varying levels of anxiety and nervousness[136]. The reasons for this were in part attributed to the unpredictability of the drop attacks. The experience of vertigo and drop attack were seen as a loss of bodily control competence for patients, which had a negative and long-lasting effect on their sense of themselves, and then anxiety and nervousness may accompany[137]. What's more, many patients experienced feelings of guilty arising from the impairment of their occupational capacity and the requisite for augmented familial assistance, a phenomenon particularly pronounced among individuals in the middle age demographic. However, there are certain limitations to using electronic health means to address mental health issues. For instance, they lack the direct human interaction that is essential in mental health interventions. Also, the collection of sensitive mental health data raises more privacy concerns. Therefore, whether to increase attention to mental health issues in this App required further research and discussion.

In conclusion, qualitative descriptive study was undertaken in this section to acquire user experiences for usage of this App. It demonstrated favorable usefulness but poor usability. Also, 7 optimization requirements were proposed by participants. In order to better fulfill user optimization requirements for the App and enhance its usability, further quantitative research of the seven optimization requirements was conducted in the next phase based on KANO model, which involved categorizing, prioritizing and calculating the importance of requirement to address the non-linear relationship between meeting user requirements and overall user satisfaction.

# 6 Requirements importance calculation

## 6.1 Research methods

### 6.1.1 Study design

Quantitative research, using questionnaire survey based on KANO model.

In part 3, user experiences and optimization requirements for the App were obtained through qualitative interviews. To further analyze user requirements for optimization, this section conducted quantitative research guided by the KANO model, calculating the importance of user requirements and subsequently ranking them as the basis for App optimization.

### 6.1.2 Research participants

Hulland et al.(ref) developed a principle for determining the sample size of the Kano model, which should be greater than 50 subjects or ten times the number of items in the Kano questionnaire. Totally, 45 participants were recruited for this study. The researcher used the convenience sampling to select the participants.

Inclusion criteria for patients or their main caregivers:

1) People who are diagnosed with vestibular dysfunction or a family member of someone with vestibular dysfunction; Family members of patients were interviewed if they demonstrated a strong willingness to participate.

2) Patients who have been recommended for vestibular rehabilitation;

3) Over 18 years old;

4) People who are able to use mobile phones independently in daily life.

### 6.1.3 Research tools

1) General Information Questionnaire (Appendix 2): developed by the researcher, which was mainly used to investigate the basic personal information of the interviewees, such as age, education level, medical insurance and average monthly family income.

2) Self-stated importance questionnaire (Appendix 5): Developed by the researcher according to the seven user requirements for optimization. Participants were asked to rate

the importance of user requirements from interviews on a 1–5 scale where 1 is for minimum and 5 for maximum importance.

3) Kano questionnaire (Appendix 5): Based on the Kano model, Kano questionnaires have been designed to quickly classify and prioritize user requirements via a 2-step system of positive/reverse questions and attribute type summarizations of product features. The questionnaire consisted of two questions for each requirement—one positive (i.e., when the requirement is realized) and one negative (i.e., when the requirement is not realized). The questions were asked according to a 5-point Likert scale, consisting of “satisfied”, “should be so”, “does not matter”, “acceptable”, and “dislike”.

4) Improvement ratio questionnaire (Appendix 5): According to the App prototype, participants were asked to give the target satisfaction and current satisfaction for each user's needs on a 1–5 scale where 1 is for minimum and 5 for maximum satisfaction, and calculated the improvement rate accordingly

### 6.1.4 Data collection

From September to November 2023, patients with chronic vestibular syndrome or their main caregivers of vertigo and Balance Center in Eye & ENT Hospital of Fudan University were selected as the study objects.

A combination of electronic and paper-based questionnaires was used. Before the survey, the researcher explained the purpose and significance of the study to the participants and guided them to it fill out the questionnaire using uniform guidance language. If they were unable to fill it out by himself, the researcher would explain it in neutral and non-suggestive language, then the subject would give a verbal answer and the researcher will fill it out for him.

The completeness of the questionnaire was checked one by one. If missing or inconsistent questionnaires were found, subjects were asked to supplement or re-fill them. After the questionnaires were collected and checked for correctness, they were imported into the database by the researcher.

### 6.1.5 Data analysis

Data analysis was performed using SPSS26.0.

The demographic data of the participants were described using frequency, component ratio, mean, and standard deviation.

Cronbach $\alpha$ coefficients, KMO values and Bartlett's sphericity test were used to conduct reliability and validity analysis of the valid KANO questionnaires.

Self-stated importance was described in terms of averages. And in the final score of user requirements importance, the self-stated importance score $H_i$ was added to each requirement, no matter what kind of type, and the value was given to avoid over-emphasizing the innovative charm requirements in Kano classification, while ignoring the basic requirements[138].

The Kano classification of user requirements was determined according to the maximum frequency of A, O, M, I, and R. If there were multiple identical Kano category percentages for the same user needs, the classification was determined according to the influence of the Kano categories, that is, M>O>A>I[139].

User satisfaction was calculated using a better-worse coefficient with the formulas:

$$SII = (A+O) / (A+O+M+I)$$

$$DDI = -(O+M) / (A+O+M+I)$$

The user satisfaction index $T_i$ is calculated by integrating the two[140]:

$$T_i = \max (|SII|\ |DDI|)$$

The absolute value of SII and DDI is between 0 and 1. The importance level of user needs is lower when the value tends toward 0 and is higher when it tends toward 1. Based on the Kano model, a single qualitative analysis is not enough to capture user requirements, so the adjustment coefficient $k$ is introduced, taking the values 1.5, 1, 0.5 and 0 to indicate the attractive requirements, one-dimension requirements, must-be requirements, and indifferent requirements, respectively[141].

The target satisfaction and current satisfaction were described in terms of averages. And the improvement rate $V_i$ of user requirements satisfaction is the quotient between target satisfaction $S_1$ and current satisfaction $S_0$[138]:

$$V_i = S_1 / S_0$$

The greater the value of the improvement rate, the greater the gap between the current state of the requirement and the user's ideal state of the requirement, and the more it needs to be optimized.

The importance of user requirements was calculated based on the classification of user requirements by Kano model and combining various factors, including user satisfaction index, Kano classification requirements, improvement rate of user satisfaction and self-stated importance score. Combining these factors, the final goal was to obtain a scientific and reasonable comprehensive score of user requirements importance $Z_i$[138]:

$$Z_i = (1 + T_i)^k \times V_i \times H_i$$

Then, the user optimization requirements were sorted in order of importance.

### 6.1.6 Ethical considerations

The study has got approval from the Ethics Committee of Fudan ENT Hospital (reference No. 2019091). The respondent voluntarily participated in the project research, and signed an informed consent form. This study may involve collecting sensitive health information, so the research should ensure that data is encrypted and only accessible to authorized personnel.

### 6.1.7 Quality control

1) The data collection process strictly followed the standardized questionnaire issuing procedures and used the same filling guidelines. When the questionnaire was collected, the quality of the questionnaire was checked on the spot. If there were any missing items or invalid questionnaires, the subjects were asked to supplement.

2) The questionnaire data were typed in SPSS 26.0 by two people, and SPSS 26.0 was used for preliminary analysis of the data to check whether there were any omissions and logical errors, so as to ensure the authenticity and accuracy of the data.

## 6.2 Research results

### 6.2.1 Demographic data

A total of 45 questionnaires were distributed, and respondents spent no less than 300 s answering them, of which 39 results were valid, representing a return rate of 87%. 6

questionnaires were excluded due to incomplete data. The general information of respondents is shown in Table 8.

Table 8 The sample characteristic (N=39)

| **Project** | **Samples (*N*=39)** |
|---|---|
| **Gender** | |
| Male | 19(48.72%) |
| Female | 20(51.28%) |
| **Age** | 48.64 ± 10.35 |
| **Educational Lever** | |
| Junior high school and below | 13(33.33%) |
| Senior high or vocational school | 15(38.46%) |
| Undergraduate | 9(23.08%) |
| Master or above | 2(5.13%%) |
| **Employment Status** | |
| Student | 4(10.26%) |
| Employed | 17(43.58%) |
| Unemployed | 4(10.26%) |
| Retired | 13(33.33%) |
| Others | 1(2.57%) |
| **Years of Diagnose** | |
| Less than one year | 14(35.90%) |
| One to three years | 19(48.71%) |
| Three years or more | 6(15.39%) |
| **Accompanying Symptoms** | |
| Tinnitus | 17(43.58%) |
| Headache | 15(38.46%) |
| Hearing loss | 18(46.15%) |
| Blurred vision | 15(38.46%) |
| Others | 6(15.39%) |
| **Underwent Vestibular Rehabilitation Before** | |
| Yes | 21(53.84%) |
| No | 18(46.16%) |

### 6.2.2 Reliability and validity analysis

Before the classification and calculation, Cronbach $\alpha$ coefficients were used to conduct reliability analysis, KMO values and Bartlett's sphericity test were used to conduct validity analysis of the valid KANO questionnaires.

Table 9 showed that the Cronbach *α* coefficients of the positive questions and the reverse questions were 0.918 and 0.879, respectively, demonstrating good internal consistency and reliable survey results. KMO values were 0.628 and 0.832, respectively, the cumulative variance contribution rates were 71.694% and 79.941%, and passed the Bartlett's sphericity test ($p < 0.05$), showing that the questionnaire had good structural validity and the research item information could be effectively extracted.

Table 9 Reliability and validity of KANO questionnaire

| KANO Questionnaire | Sample Size | Cronbach *α* coefficients | KMO values | Bartlett's sphericity test | | |
|---|---|---|---|---|---|---|
| | | | | Approx. *Chi-Squire* | *df* | ***p*** |
| Positive Questions | 39 | 0.918 | 0.628 | 352.359 | 66 | .000 |
| Reverse Questions | 39 | 0.879 | 0.832 | 516.361 | 66 | .000 |

### 6.2.3 User requirements classification

Requirements analysis was based on KANO model, and the maximum frequency method was employed to determine the attributes of each user requirement. If there were multiple identical Kano category percentages for the same user needs, the classification was determined according to the influence of the Kano categories, that is, M>O>A>I.

In this study, U1, U4, U5 represents attractive requirements, U2 represents one-dimensional requirements, U7 represents as indifferent requirements, and U3, U6 represents must-be requirements. The details of each item are shown in Table 10.

Table 10 Kano classification of user requirements (N=39)

| User Requirements | Kano Attribute Category | | | | | Final Category |
|---|---|---|---|---|---|---|
| | A | M | O | I | R | |
| U1 | 19 | 5 | 3 | 10 | 2 | **A** |
| U2 | 12 | 8 | 15 | 4 | 0 | **O** |
| U3 | 7 | 18 | 3 | 11 | 0 | **M** |
| U4 | 16 | 9 | 4 | 8 | 2 | **A** |
| U5 | 15 | 12 | 5 | 7 | 0 | **A** |
| U6 | 5 | 19 | 8 | 5 | 2 | **M** |
| U7 | 13 | 5 | 1 | 20 | 0 | **I** |

Notes: Attractive requirements (A), One-dimensional requirements (O), Must-be requirements (M), Indifferent requirements (I), Reverse requirements (R).

### 6.2.4 User requirements importance calculation

#### 4.2.4.1Self-stated importance

The self-stated importance $H_i$ within effective questionnaires underwent systematic analysis and categorization. The mean scores, rounded to the nearest whole number, were computed for each requirement, serving as a quantitative representation of the self-stated importance attributed to user needs. The precise outcomes of this analytical process are delineated in Table 11.

Table 11 Self-stated importance of user requirements (N=39)

| Serial Number | User Requirements | Self-stated Importance ($H_i$) |
|---|---|---|
| U1 | Larger text display | 3 |
| U2 | Understandable language | 5 |
| U3 | User-friendly patterns | 2 |
| U4 | Appropriate voice prompts | 4 |
| U5 | Rehabilitation exercises time-reminder | 4 |
| U6 | Appointment register and follow-up visit instruction | 4 |
| U7 | More attention to psychological condition | 4 |

#### 4.2.4.2 Improvement ratio

The target satisfaction $S_1$ and current satisfaction $S_0$ are shown in Table 12. And the improvement ratio $V_i$ was calculated to ascertain which aspects exhibit significant potential for optimization.

Table 12 Improvement ratio of user requirements (N=39)

| User Requirements | Current Satisfaction ($S_0$) | Target Satisfaction ($S_1$) | Improvement Ratio ($V_i$) |
|---|---|---|---|
| U1 | 4 | 4 | 1 |
| U2 | 3 | 5 | 1.67 |
| U3 | 2 | 4 | 2 |
| U4 | 3 | 4 | 1.33 |
| U5 | 2 | 4 | 1.67 |
| U6 | 3 | 4 | 1.33 |
| U7 | 3 | 4 | 1.33 |

#### 4.2.4.3 User requirements importance

User satisfaction *Ti* was calculated using a *better-worse* coefficient, which is shown in Table 12.

Based on the Kano model, a single qualitative analysis was not enough to capture user requirements, so the adjustment coefficient *k* is introduced, taking the values 1.5, 1, 0.5 and 0 to indicate the attractive requirements, one-dimension requirements, must-be requirements, and indifferent requirements, respectively.

Combining all factors mentioned above, the comprehensive score of user requirements importance *Zi* were calculated based on the formula referenced in Chapter 4, Section 1.5, which is shown in Table 13.

Table 13 User requirements importance calculation results (N=39)

| User Requirements | KANO Category | SII | DDI | *Ti* | *Hi* | $V_i$ | *k* | ***Zi*** |
|---|---|---|---|---|---|---|---|---|
| U1 | A | 0.59 | -0.22 | 0.59 | 3 | 1 | 1.5 | **6.01** |
| U2 | O | 0.73 | -0.59 | 0.73 | 5 | 1.67 | 1 | **14.45** |
| U3 | M | 0.26 | -0.54 | 0.54 | 2 | 2 | 0.5 | **4.96** |
| U4 | A | 0.55 | -0.30 | 0.55 | 4 | 1.33 | 1.5 | **10.26** |
| U5 | A | 0.51 | -0.46 | 0.51 | 4 | 1.67 | 1.5 | **12.39** |
| U6 | M | 0.35 | -0.73 | 0.73 | 4 | 1.33 | 0.5 | **5.32** |
| U7 | I | 0.36 | 0.15 | 0.36 | 4 | 1.33 | 0 | **0** |

Notes: Attractive requirements (A), One-dimensional requirements (O), Must-be requirements (M), Indifferent requirements (I), Reverse requirements (R), User satisfaction (*Ti*), Self-stated importance ($H_i$), Improvement ratio ($V_i$), the adjustment coefficient (*k*), User requirements importance ($Z_i$).

### 6.2.5 Define optimization strategies

According to the final results of KANO questionnaire, user requirements items were sorted in order of importance (Table13). Researcher then collaborated with UI designers and software developers to formulate specific optimization strategies to realize these high importance requirements. Based on the previous interview results and the feasibility of strategies, the following three optimization suggestions for better usability are finally determined, including more understandable language, adding rehabilitation exercises time-reminder and personalized font size. The optimization process was conducted during Dec 2023 to Jan 2024. The post-optimized design and content have garnered recognition from specialists. Specifically, as follows.

4.2.5.1 More understandable language

Based on the interview results, it was unanimously believed that the poor readability of App prototype was primarily manifested in the Medication Guide module, which was shown in Figure 13a.

Therefore, without deviating from the original intended meaning, researcher rephrased the medication guidelines using a more accessible language style. Furthermore, with the goal of improving readability and aesthetic appeal, designers restructured the layout and incorporated specific colors as well as graphic pattern to ensure users can efficiently find the information they seek, which was shown in Figure 13b.


Figure 11 Medication Guide module. (a) Before optimization; (b) After optimization.

### 4.2.5.2 Adding rehabilitation exercises time-reminder

The potential-users engaged in qualitative and quantitative research collectively acknowledge the paramount importance of enhancing compliance in vestibular rehabilitation. They asserted the necessity for appropriate reminders, as individuals commonly tended to forget taking rehabilitation exercises, particularly when symptoms exhibited improvement.

Therefore, in an effort to prompt users to engage in rehabilitation without causing undue inconvenience, a "daily scheduled reminder" mechanism was implemented within the APP-VRT. Drawing upon practices from other mHealth Apps, like Apple Health, etc., notifications were systematically dispatched to users' mobile phone at designated times to remind them to undertake their daily rehabilitative training regimen in App, which was shown in Figure 14.

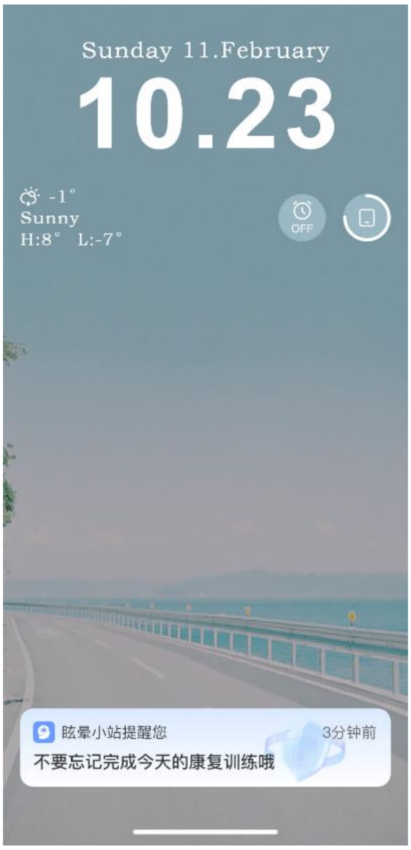



Figure 12 Rehabilitation exercises time-reminder

4.2.5.3 Personalized font size

Some participants contended that the font in the App prototype was undersized, potentially impacting their usability. However, there was also a contingent of users who argued that the font should not be excessively large, as it may compromise the aesthetic appeal of the App and inadvertently convey the impression that the App was exclusively designed for the elderly, thereby diminishing younger user engagement.

Therefore, taking into account various opinions, researcher and designers added the "text size adjustment" function in the App. This allowed users to customize the font size within the App according to their individual preferences, as illustrated in Figure 15.

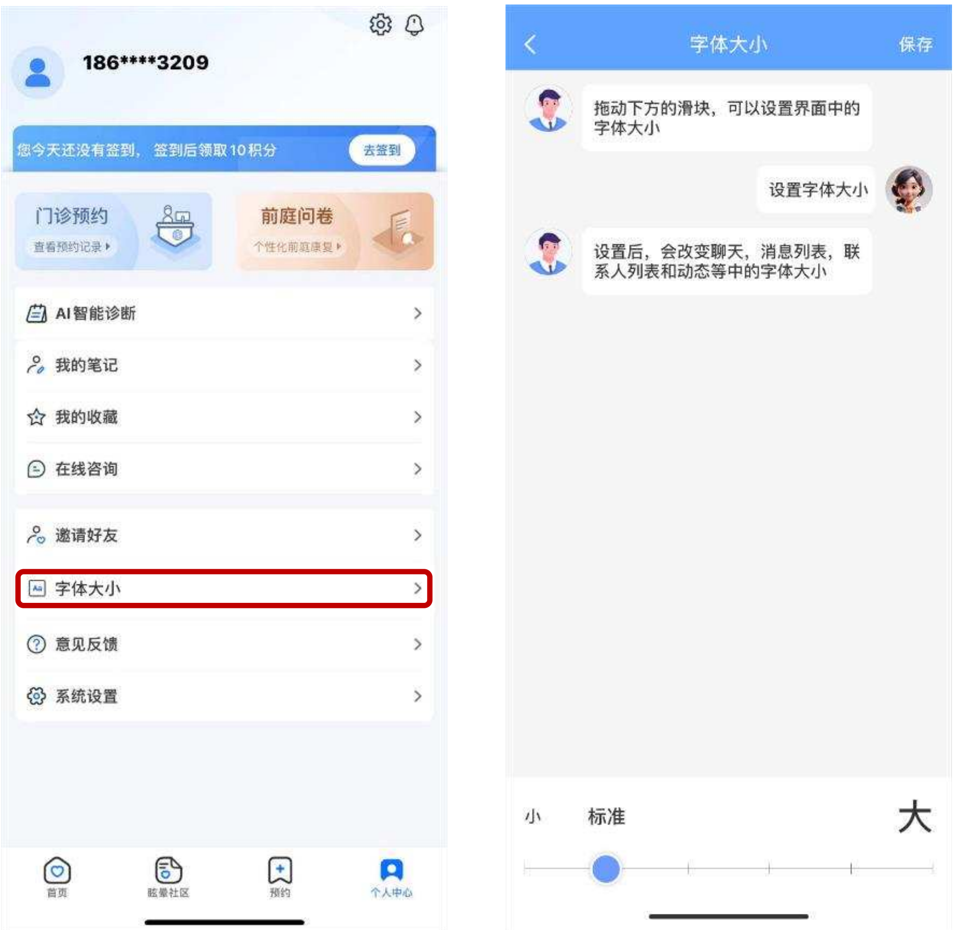



Figure 13 Personalized text size adjustment

## 6.3 Discussion

This section prioritized user requirements in accordance with the KANO model, and then synthesized qualitative and quantitative research results to determine the optimization strategy for the App prototype.

The quantitative results showed that the “more attention to psychological condition” exhibited minimal importance. However, previous study has indicated that over half of individuals suffered from chronic vestibular syndrome experienced stress related to money, work, or family responsibilities at a level that affects their mental health[142]. One plausible explanation lied in the lack of optimism among people regarding the efficacy of digital interventions in enhancing mental health, despite the various psychological issues they encountered. The translation of psychosocial interventions into digital formats, deemed digital mental health interventions (DMHIs)[143], had the potential to overcome some existing barriers to traditional care and increased access to mental health support and resources. However, engagement with these technologies remains to be an ongoing issue, varies from study to study[144]. For example, a review found that the rate of participant adherence to internet-delivered cognitive behavioral therapy can less than 10%[145]. Similarly, systematic comparisons on DMHIs found that the real-world acceptability can be lower than traditional treatment[146]. A range of factors can influence acceptance of DMHIs, such as the relevance of information to the user provided by a digital intervention[147], a lack of user motivation to persist with a self-guided intervention[148], and poor user experience with the technology[149]. Therefore, after comprehensive consideration, ENT specialists and software developers unanimously opined that the domestic conditions currently were not yet conducive for the utilization of mobile Apps to conduct systematic psychological therapy. That is to say, if users express a desire to receive psychological assistance or treatment during the utilization, this App will recommend them to seek the assistance of qualified professionals in offline settings.

Another challenge of optimization pertained to the educational materials on medication guidelines. The study results indicated that enhancing the readability of medication guidelines was one of the most important needs of app users. This may be attributed to the fact that pharmacotherapy remained one of the major interventional strategies in vertigo managements[150], especially during the acute exacerbation phase in CVS patients[151]. However, patients from all age groups and conditions faced challenges when taking medications, such as integrating them into the daily routine, understanding their effects and side effects, and monitoring outcomes[152]. In this context, a reliable medication guidance, which could meet patient’s requirements, became critical. For better usability and acceptance, the education section could be written in an easy-to-understand language and provide an added value compared with the patient information sheet, which was consistent with the findings of this study[153]. Therefore, researcher endeavored to enhance the readability of medication guidelines and employed a layout that effectively emphasized key points.

In conclusion, optimization was completed in this section to better usability according to the user optimization requirements, combining qualitative and quantitative results. The subsequent phase would evaluate the usability of this post-optimization App.

# 7 Usability evaluation

## 7.1 Research methods

### 7.1.1 Study design

Quantitative research, using user testing and questionnaire method.

### 7.1.2 Research participants

The sample size was in accordance with the existing literature, where Kushniruk[154] and Vizri[155] have shown that 70% of severe usability problems can be discovered by the first five users and up to 85% by the eighth user, following which less problems tend be identified, and these problems are also less significant[156]. Using convenience sampling method, 20 users were recruited to conduct the usability testing.

### 7.1.3 Research tools

System usability scale (SUS, Appendix F): It is typically administered immediately after interaction with the product, allowing users to record their initial feelings and responses[157]. It consists of ten questions, providing an estimate of overall usability of the intervention in the minds of users. The answer to each question ranging from strongly disagree (1) to strongly agree (5)[158]. The final SUS score ranges from 0 to 100 after converting. Scores of above 68 are considered to be acceptable or good, while 68 or below indicate poor or unacceptable usability[159]. Studies have shown that the scale is not only versatile, concise and widely used, but also fast and accurate[72]. And some studies have pointed out that SUS also has good reliability when studying small sample size[160].

### 7.1.4 Data collection

During January and February 2024, 20 potential users were selected as the subjects. Based on the function of the prototype, the test task was designed, which was consists of four parts:

1) Complete a vertigo log: Users independently complete the entry of a vertigo log according to the guidance of the home page, including the duration of vertigo, tinnitus or hearing loss, drop attack or not, precipitating factor of vertigo, and finding this record after submitting it.

2) Get personalized vestibular rehabilitation programs: According to the guidance on the home page, users complete the vestibular function screening questionnaire and some balance tests in this part, until receiving a personalized rehabilitation plan.

3) Post a note: Users post a note with at least one picture in the Vertigo community.

4) Make an appointment: Users successfully make an appointment with a desired doctor in the App and find the appointment record independently.

When the informed consent process was finalized, participants proceeded to complete surveys regarding their demographic information. The researchers then provided a detailed explanation of the evaluation process that would follow. Users then completed user testing by interacting with the App according to the described tasks.

In user testing, the effectiveness of the system was assessed based on how well participants completed tasks and the frequency of errors, whereas efficiency was gauged by the amount of time required to finish each task. To evaluate task completion, three distinct categories were used: "completed with ease" for instances where users executed tasks effortlessly without any assistance from the test leader; "completed with difficulty" for cases where users completed the task with some minor challenges or occasional help from the test leader; and "failed to complete" for situations where users could not finish the task despite receiving hints. An error was recorded whenever a participant made mistakes that they could not rectify or when errors impeded their ability to progress. The efficiency of task completion was quantified by recording the time taken for each task and then calculating the average duration for each task across all participants[161].

After the user testing, participants were asked to fill out the SUS to gather their initial impressions of the app and evaluate its overall satisfaction.

### 7.1.5 Data analysis

Data analysis was conducted in SPSS version 26.0. SUS Scores were calculated according to Brooke's guidelines[162]. The procedure involved aggregating the scores from each of the ten individual items. Specifically, for items 1, 3, 5, 7, and 9, one point was deducted from the total score. Conversely, for items 2, 4, 6, 8, and 10, the score was recalculated by subtracting the response value from 5. After adjusting the scores as described, the total sum was then multiplied by 2.5 to derive the overall satisfaction metric.

Ethical considerations

1) The study has got approval from the Ethics Committee of Fudan ENT Hospital (reference No. 2019091).

2) The respondent voluntarily participated in the project research, and signed an informed consent form.

3) The personal data and the incidence of illness entered by the participants for the user test will not be disclosed under any circumstances.

## 7.2 Research results

### 7.2.1 Demographic data

The 20 participants had a variety of backgrounds and characteristics. Ten participants were female and others were male. Half of patients had senior high or vocational school education (50%). Sixty percent were diagnosed within two years while 40% were diagnosed 2 years ago. Details are shown in Table 14.

Table 14 The sample characteristic (N=20)

| Serial Number | Gender | Age | Marriage | Education Level | Disease Duration |
|---|---|---|---|---|---|
| 1 | Male | 50 | Married | Senior high or vocational school | 4 |
| 2 | Female | 35 | Unmarried | Undergraduate | 2 |
| 3 | Female | 33 | Married | Undergraduate | 1 |
| 4 | Male | 48 | Married | Senior high or vocational school | 3 |
| 5 | Female | 26 | Unmarried | Undergraduate | 1 |
| 6 | Female | 27 | Unmarried | Undergraduate | 1 |
| 7 | Female | 45 | Married | Senior high or vocational | 3 |
| 8 | Male | 36 | Married | Senior high or vocational | 2 |
| 9 | Female | 30 | Unmarried | Senior high or vocational school | 1 |
| 10 | Male | 37 | Married | Undergraduate | 3 |
| 11 | Male | 56 | Married | Primary school or below | 7 |
| 12 | Male | 49 | Married | Senior high or vocational | 4 |
| 13 | Female | 31 | Married | Undergraduate | 1 |
| 14 | Male | 37 | Married | Undergraduate | 2 |

| | | | | | |
|---|---|---|---|---|---|
| 15 | Female | 28 | Unmarried | Senior high or vocational | 1 |
| 16 | Female | 33 | Married | Undergraduate | 3 |
| 17 | Female | 50 | Married | Senior high or vocational | 4 |
| 18 | Male | 36 | Married | Undergraduate | 2 |
| 19 | Male | 42 | Married | Senior high or vocational school | 1 |
| 20 | Male | 31 | Unmarried | Senior high or vocational school | 2 |

### 7.2.2 Effectiveness

The completion rates for each task were all greater than or equal to 80%, demonstrating a commendable level of effectiveness, which was presented in Figure 16. Specifically, Tasks 2 (get personalized vestibular rehabilitation programs) was the most difficult to complete with 20% failure rate. The completion rate of Task 1 and 4 (complete a vertigo log, make an appointment) were situated at a higher level. Tasks 3 (post a note) was completed with ease by all.

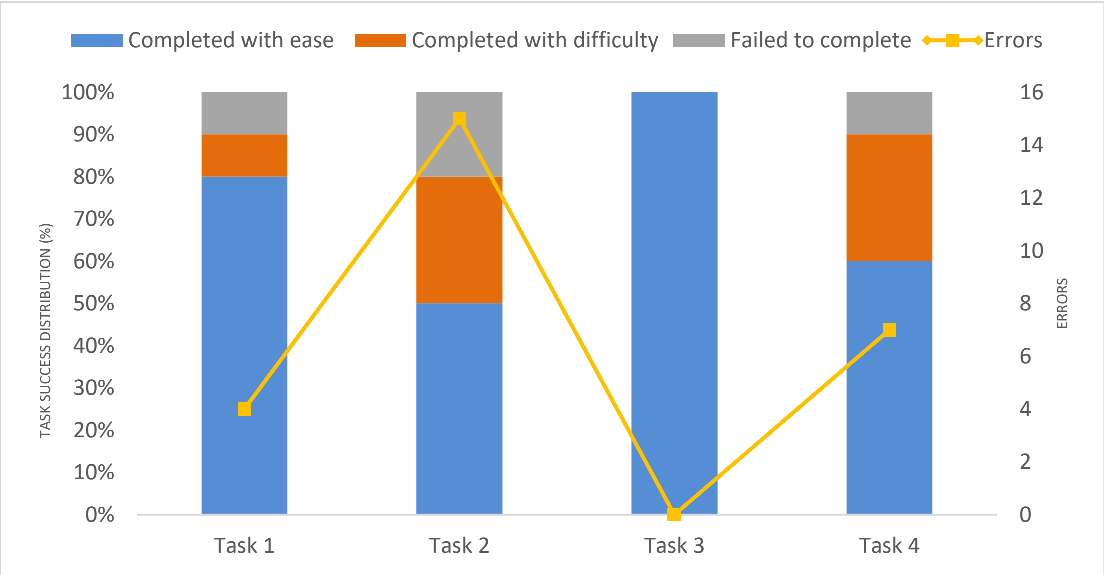



Figure 14 Task completion and error rate

The error rate mirrored task completion difficulty with Tasks 2 and 4 having more errors while Tasks 3 was completed without any errors, which was also shown in Figure 13. The largest number of errors was quite high at 15 and 7. Errors were especially prevalent with steps related to (1) documenting the duration of the open-eye/closed-eye standing phase in gait testing accurately, (2) associating personal information before scheduling a clinic consultation, (3) documenting the onset time and duration of vertigo.

### 7.2.3 Efficacy

As may be seen in Table 15, Tasks 2 and 4 consumed the longest amount of time, as might be expected given the difficulties with task completion and errors mentioned above. On the other hand, Tasks 3 took the shortest times.

Table 15 Time on tasks

| | | Task 1 | Task 2 | Task 3 | Task 4 |
|---|---|---|---|---|---|
| Time per task (min) | Mean (SD) | 97 | 322 | 45 | 203 |
| | Range | 70-113 | 303-332 | 35-61 | 87-363 |

### 7.2.4 Satisfaction

The average SUS score for the whole group was 77.75 (SD 10.27), indicating good satisfaction across this mHealth App users, as seen in table 16.

Table 16 Overview of SUS scores

| **System usability score** | **Score** |
|---|---|
| **SUS score, total, mean ± SD** | **77.75±10.27** |
| **SUS score, each item** | |
| Item 1 | 3.9 |
| Item 2 | 1.5 |
| Item 3 | 4.3 |
| Item 4 | 2.1 |
| Item 5 | 4.6 |
| Item 6 | 1.5 |
| Item 7 | 3.8 |
| Item 8 | 1.3 |
| Item 9 | 3.7 |
| Item 10 | 2.8 |

## 7.3 Discussion

This section provided insight into the usability of the App among people with chronic vestibular syndrome to support App-based symptom management and rehabilitation exercises. This section evaluated the usability of App systematically. The different components of usability, including efficiency, effectiveness, and satisfaction, were all judged as good by CVS patients.

Reasons that Task 2 and 4 (get personalized vestibular rehabilitation programs, make an appointment) proved more difficult might be related to the task itself, to user practice, and also to needed redesign. These tasks were more complex, involving multiple steps and decision points, making them inherently more intricate and demanding a higher cognitive load from users, while tasks 3 (post a note) was more straightforward, with only one step.

Another possible reason is that this usability test assessed users while they were still practicing these new, more complex tasks. Since Tasks 2 and 4 required users to navigate through various menus, input personalized information, and possibly interact with external scheduling systems, users with less experience or practice were naturally more prone to encountering difficulties. This could be exacerbated by the fact that the usability test was conducted during the initial stages of users' interaction with the application, before they had fully acclimated to its functionalities[163]. Therefore, as users gain proficiency and familiarity with the application through continued use and practice, it's anticipated that the efficiency of completing Tasks will improve[164].

The overall satisfaction results indicated good usability, although not excellent. The possible reason for a few lower scores was that some individuals were not accustomed to addressing health issues through mobile devices, which was often considered unreliable. This highlights the importance of considering users' technological backgrounds and preferences when designing and evaluating mobile health solutions[165, 166]. Furthermore, additional training or support in using these platforms could potentially improve overall satisfaction and usability ratings among a broader user base[167].

Previous studies and practical experiences have highlighted that designing technologies that capture users' interest, encourage initial engagement, and sustain long-term use has consistently posed a challenge. In the healthcare sector, the stakes are even higher, as the potential intrusiveness of such technologies can lead patients to reject them outright[168]. Ensuring user satisfaction is particularly complex due to the often nonlinear and intricate nature of the user experience[169]. The user journey often involves multiple, non-sequential stages of interaction with technology, and understanding these stages is crucial for creating effective solutions. For instance, patients might initially be eager to try an application but may not continue using it over time. Conversely, individuals who have discontinued use might return to the technology later[170]. Various factors, such as age and educational background, can significantly influence how patients perceive and interact with technology, thereby affecting their overall satisfaction. Moreover, the degree to which users have incorporated technology into their daily routines can also play a critical role in their decision to lengthen its use[171]. Patients who have successfully appropriated and adapted technology into their routines are more likely to continue using these tools, as they have become an embedded part of their lifestyle. This highlights the importance of designing technologies that not only address users' immediate needs but also fit seamlessly into their broader life contexts to support long-term engagement and satisfaction.

To sum up, this App has exhibited favorable usability and garnered an acceptable level of user satisfaction. What’s more, the usability also requires subsequent dynamic evaluations to ensure long-term acceptability, as well as high satisfaction.

# 8 Conclusion

## 8.1 Conclusion

1) This research determined the modules and functions of App for chronic vestibular syndrome patients according to the results of two rounds of focus groups with specialists. The major function of this App encompassed the vertigo log and vestibular rehabilitation training.

2) This research developed an App prototype, encompassing both design and coding. Researcher was responsible for content creation and oversight, and the researcher was cooperated with software development team in code writing and testing.

3) This research acquired user experiences and requirements for the App prototype optimization by semi-structured interviews and calculated importance of requirements based on the KANO model. Three optimization strategies for better usability were finally determined, including more understandable language, adding rehabilitation exercises time-reminder and personalized font size.

4) This research evaluated the usability of App systematically, which exhibited favorable usability and garnered a notably high level of user satisfaction.

## 8.2 Innovation points

1) This research is the first to design and develop mobile App for CVS population, which will help improving the accessibility of vestibular rehabilitation, and also assist patients and healthcare professionals in symptom management.

2) It is the first to use the Kano model in the field of CVS population and vestibular rehabilitation, which could broaden the application of Kano model in the medical domain to a certain extent.

3) The design and development process of the App were based on expert discussions to make sure the credibility and quality assurance by leveraging specialized knowledge, enhancing methodological rigor and promoting interdisciplinary collaboration.

## 8.3 Limitations and Prospects

### 8.3.1 Limitations

While the usability of the app in this research has been validated and user satisfaction was relatively high based on initial trials, the clinical efficacy of the app remains to be further confirmed. Currently, there is a lack of long-term and multi-center validation studies that are necessary to comprehensively evaluate the app's effectiveness in diverse clinical settings and across a broader patient population. Future research should focus on conducting extended trials over a longer duration and involving multiple healthcare centers to ensure that the app can consistently deliver reliable and beneficial outcomes in real-world scenarios. Such studies will be crucial for establishing the app's utility as a trusted tool in clinical practice.

### 8.3.2 Prospects

In the future, rigorous randomized controlled trials will be conducted to determine the efficacy of App-based rehabilitation training and symptom management for patients with chronic vestibular syndrome.

Furthermore, the App will be continually optimized by operation team of Eye and ENT hospital of Fudan University during its usage to adapt to the ongoing advancements in technology and medicine.

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# Appendices

## Appendix 1 Discussion Guide

**Opening questions:**

To your knowledge, if there any mobile applications in the field of vertigo at home and abroad? Do your patients use mobile health applications? What are your experiences with patients using these apps?

**Topic questions:**

Do you think mobile health applications could be used to the benefit of your patients with chronic vestibular rehabilitation?

If so, what should such an app certainly contain or be able to do, for you to recommend it to your patients?

**Additional questions in case the following topics do not come up:**

Do you think these applications could be used to monitor the disease?

Do you think these applications could be used to guide rehabilitation?

## Appendix 2 General Information Questionnaire

1. Gender: ① male ② female;

2. Date of birth: _______;

3. Occupation: _______;

4. Place of origin: province/county/district;

5. Place of residence: ① rural ② town ③ city;

6. Education level: ① primary school and below ② middle school ③ high school or secondary school ④ Junior college and above;

7. Marital status: ① married ② unmarried ③ divorced ④ widowed

8. Family size: ____ persons;

9. Family monthly income: ① less than 3,000 yuan ②3000-6000 yuan ③6000-10000 yuan ④ 10,000-20,000 yuan ⑤ more than 20,000 yuan;

10. Medical payment method: ① public (medical insurance and commercial insurance, etc.) ② self-pay;

11. Your main caregivers are: ① oneself ② spouse or children ③ other relatives and friends ④ carer or nanny etc. ⑤ Others (please specify);

## Appendix 3 Interview Outlines

1. Where are you come from? How long have you been vertigo? Is it convenient for you to come to the hospital regularly to follow-up?

2. How long have you been doing vestibular rehabilitation? (What causes you cannot stick to the rehabilitation training?)

Our hospital has developed a mobile App for patients like you, let me introduce it to you. And after it, you can try it by yourself.

After the introduction and interaction with the App:

1. What do you think about this prototype?

2. What do you like or dislike about it? Do you want to use it in your daily life? Will your life be better if you use it?

3. How do you think it should be optimized? Do you have some questions about it or suggestions?

## Appendix 4 Informed Consent

Dear participants,

Hello!

This is a study conducted by the School of Nursing, Fudan University and the Eye and ENT Hospital of Fudan University. We would like to develop a mobile health application for patients with chronic vestibular syndrome, and now with the study purpose of understanding your experience and opinions about it.

We would like to inform you that, for research purposes, we will record the entire process, but we assure you that we will keep your general information and the recorded information strictly confidential to ensure that only researchers have access to the relevant information.

We sincerely invite you to participate in this study. If you are willing to participate, we will give you a gift after the data collection as a thank you. You can decide whether to participate in the study according to your personal situation, and you have the right to withdraw from the study process without being treated unfairly.

Finally, thank you for your participation!

The researcher has explained the purpose and process of the study to me, and I know that there is no harm to me. I have clarified the relevant matters of the study and agree to participate in this study.

Signature of Participant:

Date:

## Appendix 5 KANO questionnaire

**User Requirements Importance Questionnaire**

| 序号 | 需求要素 | 题项 | 重要度 | 满意度 | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1-5 分 | 满意 | 理应如此 | 无所谓 | 勉强接受 | 不满意 |
| 1 | 文字显示 | 字号较大 | | | | | | |
| | | 字号较小 | | | | | | |
| 2 | 语言理解 | 语言通俗易懂，易于理解 | | | | | | |
| | | 语言专业性强，较难理解 | | | | | | |
| 3 | 运营模式 | 有积分兑换模式 | | | | | | |
| | | 无积分兑换模式 | | | | | | |
| 4 | 语音提示 | 适当的语音提示 | | | | | | |
| | | 没有语音提示 | | | | | | |
| 5 | 康复训练提醒 | 康复训练时间发出提醒 | | | | | | |
| | | 没有康复训练提醒 | | | | | | |
| 6 | 挂号和随访指导 | 提供挂号和随访指导服务 | | | | | | |
| | | 不提供挂号和随访指导服务 | | | | | | |
| 7 | 心理状况 | 更关注患者的心理状况 | | | | | | |
| | | 不关注患者心理状况 | | | | | | |

**Improvement Ratio Questionnaire**

| 序号 | 需求要素 | 当前满意度<br>1-5 分 | 目标满意度<br>1-5 分 |
|---|---|---|---|
| 1 | 文体字号大小 | | |
| 2 | 易于理解的文字内容 | | |
| 3 | 积分兑换模式 | | |
| 4 | 语音提示 | | |
| 5 | 康复训练时的自动提醒 | | |
| 6 | 挂号和随访指导服务 | | |
| 7 | 更关注病人的心理状况 | | |

## Appendix 6 System usability scale

**System usability scale (SUS, Chinese Version)**

| 序号 | 条目 | 评分 |
|---|---|---|
| 1 | 我愿意经常使用它 | |
| 2 | 我认为它太复杂 | |
| 3 | 我认为它容易使用 | |
| 4 | 我认为我需要有经验的人帮助，才能使用它 | |
| 5 | 我认为它的多种功能整合得很好 | |
| 6 | 我认为它有很多不一致的地方 | |
| 7 | 我觉得大多数人会很快学会使用它 | |
| 8 | 我发现它使用起来很麻烦 | |
| 9 | 在使用它的过程中，我感到很自信 | |
| 10 | 在使用它前，我需要学习很多东西 | |

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Tempus fugit.

My twenty-year journey of learning nears its end, yet the life is just beginning. May I become a person who contributes to society some time.