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DIGITAL HEALTH: DEVELOPMENT OF A MOBILE APPLICATION FOR TINNITUS IDENTIFICATION AND INTERVENTION

SAÚDE DIGITAL: DESENVOLVIMENTO DE UM APLICATIVO MÓVEL PARA IDENTIFICAÇÃO E INTERVENÇÃO NO ZUMBIDO

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ABSTRACT: **Aim:** To present the development of a free mobile application designed to serve as a tool for the assessment and intervention of patients with tinnitus. **Methodology:** The application was developed in 2023 and followed three stages: planning, development, and practical application, using the JavaScript programming language. **Results:** The Zumit app includes four main features: (1) information, (2) user identification, (3) evaluation of tinnitus characteristics using the Tinnitus Handicap Inventory and Visual Analog Scale, and (4) intervention through auditory training. **Conclusions:** Zumit offers an innovative and accessible solution for assessing and managing tinnitus, with the potential to be widely adopted in clinical practice.

KEYWORDS: Mobile Application. Health Technology. Tinnitus.

RESUMO: **Objetivo:** Apresentar o desenvolvimento de um aplicativo móvel gratuito, destinado a ser utilizado como instrumento na avaliação e intervenção de pacientes com zumbido. **Metodologia:** O desenvolvimento do aplicativo ocorreu em 2023 nas etapas: planejamento, desenvolvimento e aplicação prática, usando a linguagem de programação *JavaScript*. **Resultados:** O aplicativo Zumit contempla quatro principais funcionalidades: (1) informações, (2) identificação do usuário, (3) avaliação das características do zumbido com a *Tinnitus Handicap Inventory* e Escala Visual Analógica e (4) intervenção por meio do treinamento auditivo. **Conclusões:** O Zumit oferece uma solução inovadora e acessível para avaliação e manejo do zumbido, com potencial para ser amplamente adotado na prática clínica.

PALAVRAS-CHAVE: Aplicativo Móvel. Tecnologia em saúde. Zumbido.

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INTRODUCTION

Tinnitus is characterized as the conscious perception of sound in the ear or head, in the absence of external sound stimulus. This symptom is highly prevalent in the population, negatively impacting the quality of life, sleep, ability to concentrate, speech perception and, in some cases, the mental health of affected individuals. Tinnitus' characteristics can vary in terms of location (unilateral, bilateral, or in the head), time of onset (acute or chronic), duration (intermittent or continuous), type and intensity of sound, leading to different degrees of discomfort, which can range from mild to disabling[1].

The etiology of tinnitus involves changes in both the Central Auditory Nervous System (CANS) and peripheral structures, such as hearing loss, medication use, infections, trauma, emotional factors, metabolic disorders, and chronic diseases. Interestingly, tinnitus can also be observed in individuals with normal hearing[2]. Given the multifactorial and subjective impact of this symptom, a multidisciplinary approach, involving professionals from speech-language pathology and audiology, otorhinolaryngology, physiotherapy, dentistry, and nutrition, is crucial in diagnosis.

In the diagnostic process, acuphenometry is a subjective assessment that uses techniques similar to pure tone audiometry, which allows the identification of the characteristics of tinnitus, in terms of frequency (pitch) and intensity (loudness), reported by the patient. Additionally, the application of self-assessment questionnaires, such as the Tinnitus Handicap Inventory (THI) and the Visual Analogue Scale (VAS), is essential to measure the psycho-emotional impact and the degree of discomfort, respectively, assisting in monitoring and personalizing treatment[3].

Given the subjective nature of tinnitus, treatment involves several therapeutic approaches, including counseling, use of Electronic Sound Amplification Devices (ESADs), with or without sound generators, relaxation techniques, Auditory Training (AT), masking, electrical stimulation, pharmacological interventions, surgeries and nutritional adjustments. Each intervention is indicated based on the individualized diagnosis[1,4].

Although ESADs represent an effective solution, they are not yet available through the Unified Health System (SUS) for patients with tinnitus without hearing loss, which highlights the need for investment in alternative strategies for identifying and managing the symptom. Technological developments and the popularization of smartphones, which now offer high computing capacity at affordable costs, have transformed these devices into valuable tools in the health field. In the context of tinnitus, smartphone applications offer solutions that range from diagnosis and management to treatment and monitoring, facilitating patient monitoring by health professionals[5].

At an international level, several countries have developed technological initiatives aimed at managing tinnitus, focusing on mobile applications that offer everything from sound masking to cognitive-behavioral therapy[1,4]. However, there are still significant gaps regarding the integration of these tools with comprehensive clinical assessments and personalized hearing interventions that promote continuous monitoring supervised by health professionals[4]. The importance of this innovation is directly linked to health promotion and the prevention of complications associated with tinnitus, improving the quality of life and well-being of patients, which are essential aspects of global public health[5].

Given the need to expand access to assessment and intervention tools for individuals with tinnitus, this study is justified by the lack of accessible solutions, especially in SUS, for managing this symptom. Thus, this study aims to present the development of a free mobile application, intended to be used as an instrument in the assessment and intervention of patients with tinnitus.

METHODOLOGY

This study is characterized as an innovation in hearing health through applied research, focusing on the practical development of a technological solution that contributes to the well-being of individuals affected by tinnitus. The methodology followed well-defined stages, from planning to the practical application of the Zumit application. Initially, an analysis of the clinical and technological needs for the management of tinnitus, based on the literature and the demands identified in patients and professionals of the area, was carried out.

The application development process followed the Contextualized Instructional Design (CID) method [6], which consists of planning/analysis, development and practical application, with new tools being incorporated according to the needs identified. Therefore, the following steps were carried out:

Initial schedule: stipulation and organization of time to develop the application;

Survey and analysis of requirements: communication with the team of speech-language pathologists and audiologists to understand emerging needs during the treatment of the patient with tinnitus;

System view flowchart: elaboration of the general functioning of the system that encompasses the application, people, and processes;

Creation of application functions: assessment of needs for new functions; design of the screen with the new function; development of the code for creation; implementation of the function in the application; evaluation and user feedback (step repeated according to the demand for functions);

Final tests: extensive tests and with validity for clinical research;

Product delivery: publishing the mobile application on Play Store (Android) and App Store (iOS);

Follow-up: during the clinical research, new ideas or needs that could modify the mobile application were identified.

To create the database server for registered patients (accessed only by the professional who performed the registration), a virtual machine with two virtual Central Processing Units (CPUs), 8 gigabytes (GB) of RAM and 60 GB of space, in which the Ubuntu 20.04 – Long-term Support (LTS) operating system was installed, was used. Subsequently, the following steps were executed:

1. Use of Node Version Manager (NVM) to install Node.js (open source software that allows JavaScript code to run outside of a web browser), automatically installing Node Package Manager (NPM), JS package manager or modules;
2. Use of Advanced Packaging Tool (APT) (Ubuntu package manager) to install MongoDB (NOSQL database), Nginx (open source web server software) and other dependencies;
3. Carrying out the necessary configurations;
4. Running Parse Server so that the mobile application becomes able to access the database

During the full development of the application, a Mac mini (Apple) with an Intel processor and 8GB of RAM and macOS Catalina operating system was initially used. During the creation process, the need to migrate to a Mac Mini with an M1 processor and 8GB of RAM and macOS Monterey operating

system was identified, due to its superior performance. In addition, the JavaScript language was used to write the code in a single project for both platforms (Android and iOS).

The game engine used was NodeJS, with the following frameworks: React Native (a JavaScript library created to develop applications for Android and iOS systems natively), Expo (allows easy access to the device's native Application Programming Interfaces (APIs) without the need to install any dependencies or change code) and Turtle (helps compile the application project into the final binaries for iOS and Android systems). Later, the EAS helper (from the eas-cli project) was used to replace Turtle to perform local compilations and thus generate the final binaries.

It is important to highlight that to use each framework mentioned above, it was necessary to previously read the respective documentation to understand its functions, such as the use of possible APIs, and limitations that will outline the final project.

The Parse Server foundation was used as an API service to send and receive data from the mobile application and store data in MongoDB. In addition, sound development and editing were performed using Audacity and Adobe Audition, and workflows and diagrams were created using Microsoft Visio.

The sounds developed in the Audacity program for performing acuphenometry and auditory training followed the characteristics of the frequencies of 125, 250, 500, 750, 1k, 1.5k, 2k, 3k, 4k, 6k, 8k, 9k, 10k, 11.2k, 12.5k, 14k, 16k, 18k, 20k Hz. For each of them, two types of continuous sound were selected: pure tone and narrow-band with intensity 1 (maximum) and duration of 3 seconds. Later, in the reproduction tests on smartphones, it was found that several of the sound stimuli, especially those of high frequencies, were of unsatisfactory quality. Therefore, the intensity was normalized using the Adobe Audition software.

Throughout the app creation phase, the GIT tool, which consists of a source code version control system and allows the developer to access the history of each modification made to the application and, therefore, allows the reversal of desired changes at any time, was used.

During internal testing of the iOS platform, the binary was sent to TestFlight, the App Store's testing platform; while on the Android platform, it was hosted on a private server to make it possible to access it from smartphones with the Android operating system. Finally, in the final distribution, the binaries were sent to the official platforms of the respective companies: App Store (Apple) and Play Store (Google).

RESULTS

The prototype of the free mobile application for interactive tinnitus assessment and intervention, called Zumit, which includes the functions of user identification, assessment, questionnaires, intervention, encouragement and conversation with the patient, was developed.

The initial access to the application is performed by the speech-language pathology and audiology therapist who performs acuphenometry, THI and VAS questionnaires, treatment planning, generates the access code and, finally, verifies and audits the activities performed by the patient, who will be guided on the installation, how to access the system and perform the training at home. To remind individuals about daily auditory training, notifications were implemented through the patient database server, thus, notifications are sent every 8 hours every day.

The gamification process of the application's functionalities is composed of a combination of the following elements: mascot Zumitinho, unique daily goals and feedback on successes and failures. In addition, a level advancement in the auditory training was developed, as shown in Figure 1, in which the

frequencies to be displayed are limited according to the level of difficulty, which is proportionally related to the correct answers in the AT of that day.

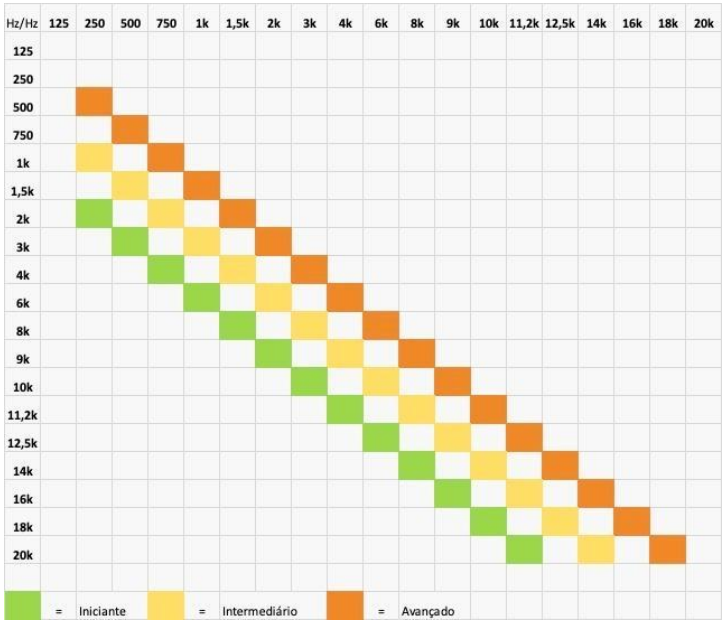

Figure 1 – Relationship between difficulty levels and frequencies presented
Source: Authors of the study

It is important to emphasize that, each time the training is started, the patient starts at the beginner level and, as they choose the correct alternatives, they advance to the intermediate and advanced levels, achieving new unique goals throughout the daily practice.

In the first stage, called Authentication, it is possible to access the application as a patient by entering a code provided by the speech-language pathology and audiology therapist or authenticate as a professional, entering the previously registered email and password (Figure 2).

When the professional is admitted, the speech-language pathology and audiology therapist has access to the following topics: Information; THI, VAS, Exams and Audit. Initially, in face-to-face care, the patient is registered in the application, providing the e-mail, Individual Taxpayer Registry (CPF), General Registry (RG), clinic registration, full name, gender, date of birth, telephone, city, socioeconomic classification and, if applicable, information about the previously configured treatment (Figure 2).

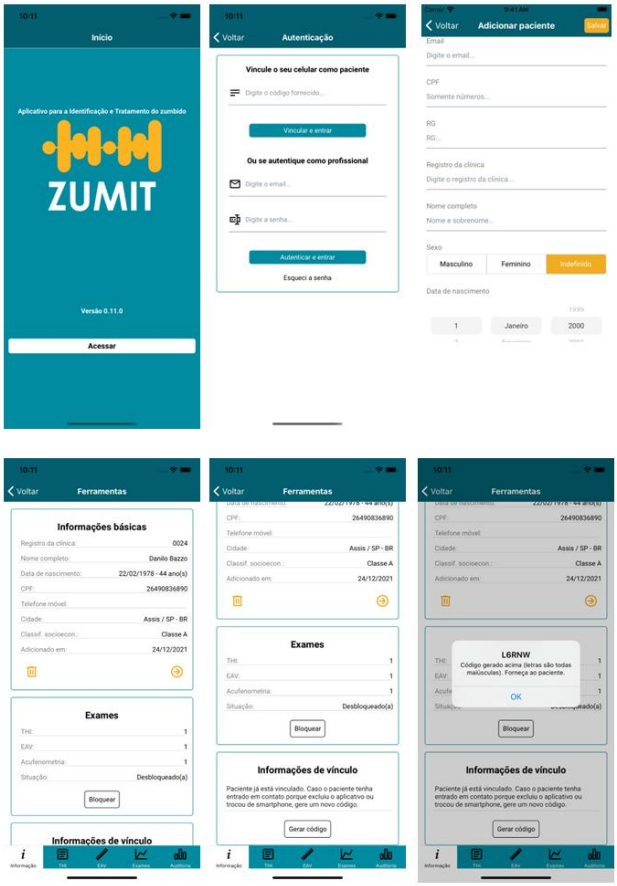

Figure 2 – Initial screens for registering and accessing the application
Source: Authors of the study

Immediately after, when accessing the patient's name, the professional is directed to the patient's information tab, which contains all previously registered data, as well as information regarding treatment and affiliation, where the access code to be sent to the patient is generated, as shown in Figure 2.

The following tabs include THI and VAS, which can be completed directly by the speech-language pathology and audiology therapist together with the patient and, when completed, the record is saved in the databases. In the next topic, called Exams, a notification is displayed asking the smartphone volume to be at maximum and, only after the action is performed, it is possible to select the pure tone or narrow-band as a stimulus when performing acuphenometry or the selection of white noise when searching for the minimum masking level (MML), as well as the frequency and intensity of the sound, data that can be saved and compared between the pre- and post-AT conditions, as shown in Figure 3.

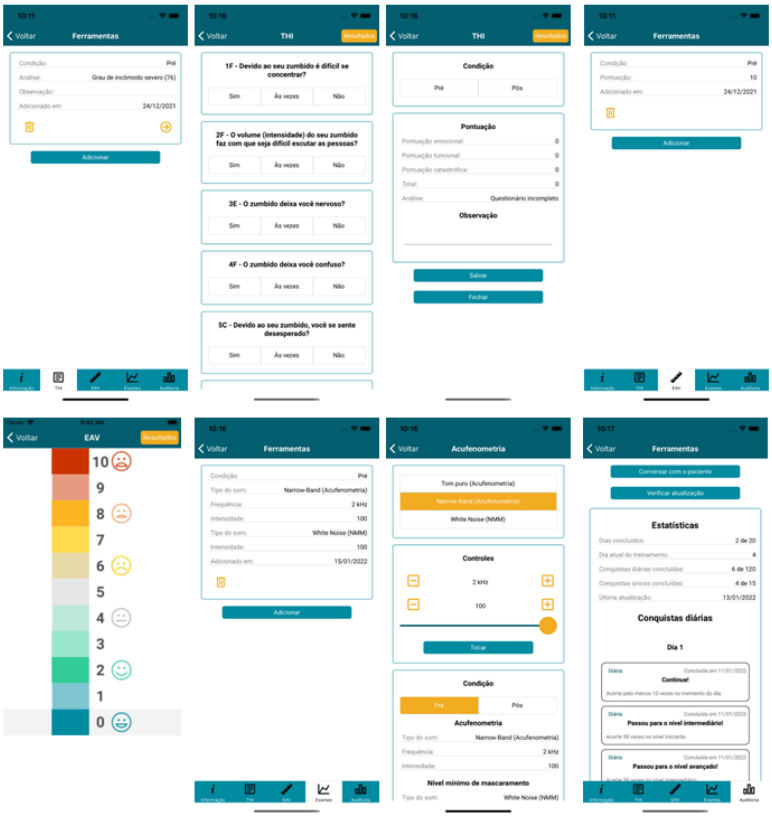

Figure 3 – Patient assessment screens present in the application
Source: Authors of the study

The next screen is the Audit topic, consisting of the days of AT completed by the patient, the number of unique achievements completed, the current training day and the date of the last update of that topic. Also in the Audit, there is the option “Talk to the patient”, in which the speech-language pathology and audiology therapist answers any questions reported by the patient about their therapeutic process, further assisting with treatment adherence (Figure 3).

When the patient logs into the application for the first time, a welcome screen is automatically displayed, in which the mascot Zumitinho provides the first instructions on how to access the system and is limited to the following topics: Welcome and information; Auditory Training; Progress and achievements; and Help. The Welcome and Information section (Figure 4) provides instructions on how to use the application, as well as specific data on the treatment, recommendations on the next steps for the AT, individual progress up to the moment of access and, finally, application information.

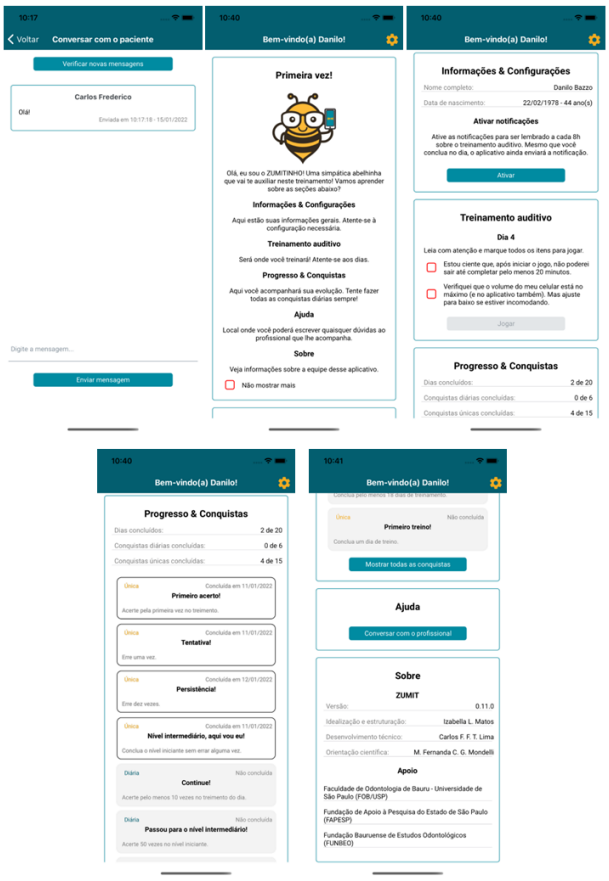

Figure 4 – Patient access and monitoring screens
Source: Authors of the study

The Auditory Training screens consist of the treatment itself, that is, the activities that the patient must perform during the period previously established by the speech-language pathology and audiology therapist. In this stage, the individual must listen to the sound stimuli presented and choose the icon corresponding to the question presented, which is the lowest or highest pitch, as seen in Figure 5. On this screen, it is also possible to see the remaining time and the number of errors and correct answers, followed by the demonstration of the sound stimulus and, when finished, the attempt is completed. In the event of an error in the answer, the patient is encouraged to try again. After each training session, the patient is directed to the Progress and Achievements section (Figure 5), rewarded for success in each task or even for persistence, in which trophies are earned for errors.

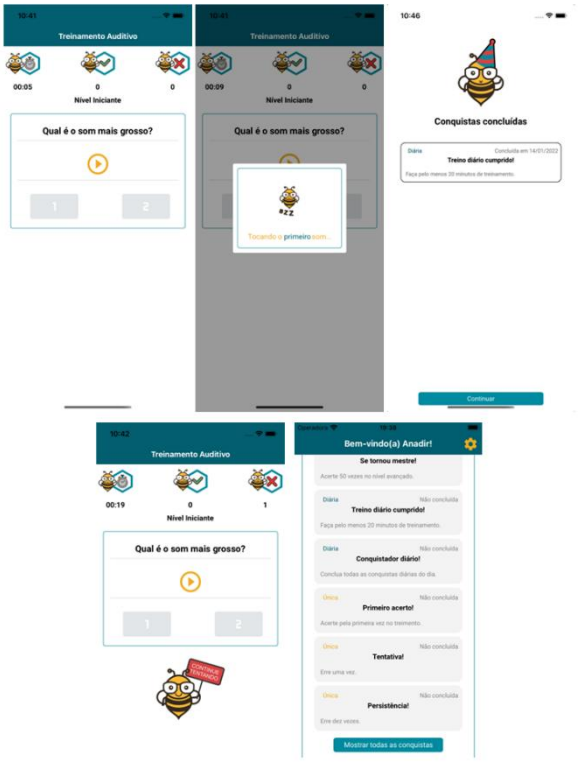

Figure 5 – Auditory training and patient progress screens present in the application
Source: Authors of the study

Finally, on the Help screen, the patient can contact the professional directly, clarifying any doubts quickly and appropriately, as shown in Figure 5, similar to the speech-language pathology and audiology therapist's access screen.

DISCUSSION

In the area of mobile application development focused on healthcare, several methods can be used, such as Systematic Design of Instruction (SDI), Contextualized Instructional Design (CID), User-Centered Design (UCD), and the Systems Development Life Cycle (SDLC). All of these methods follow fundamental steps of analysis, design, development, implementation, and evaluation, and each of these must be well-defined and structured to ensure that the application achieves its objectives. In addition to technical development, it is essential to consider usability and the interest of the target user to ensure that the application fulfills its purpose effectively. In this context, gamification has stood out as an efficient strategy for increasing user engagement, motivation and involvement, as demonstrated in several fields, including the health field [7].

In an international study[8], gamification, although it did not show a significant impact on treatment adherence in a wellness intervention, increased the cognitive and affective engagement of participants, in addition to arousing greater interest and inspiration. This type of approach is also discussed by other authors[9], who highlight user collaboration, reward, explicit progress, goals and positive reinforcement as the main elements of gamification in health applications, all present in the application developed in this study, to promote compliance with therapeutic activities.

Despite the growth in the creation of applications for tinnitus management, most focus on masking the sound or providing temporary relief from the symptom, with few offering assessment and treatment conducted by professionals, such as speech-language pathologists and audiologists[5,10]. This fact is corroborated by authors[11], who warn of the presence of applications with inadequate information available on various platforms, which underscores the importance of careful guidance by health professionals. On the other hand, a review[10] on smart self-help services for the diagnosis and treatment of tinnitus concluded that many of these resources are effective, as long as there is a reliable interaction between the patient and technology. This premise was one of the bases for the development of the Zumit application, which encourages patient involvement under the supervision of the speech-language pathologist and audiologist, ensuring adequate monitoring.

National authors[5] emphasize the need to adapt the application approach to the specific needs of each patient, allowing self-management or joint practice with the speech-language pathologist and audiologist, according to individual conditions. In the development of personalized therapeutic plans, it is essential to use assessment instruments, such as THI and VAS, which, according to previous studies[12–14], present a significant correlation with regard to the assessment of tinnitus discomfort, being fast, accessible, and easy to apply.

Another important method of subjective assessment is acuphenometry, which, although it does not directly correlate with the level of reported discomfort, is essential for determining the most appropriate type of sound stimulus for treatment, in addition to allowing the measurement of therapeutic progress[3]. In the field of intervention, authors[15] developed an application that offers sound therapy combined with Cognitive-Behavioral Therapy (CBT) for the treatment of tinnitus, demonstrating promising results. Although similar to Zumit in its ability to perform acuphenometry, the application[15] differs in that it uses sound therapy exclusively for masking and includes CBT directly in the platform.

Authors[16] highlight significant differences in the auditory abilities of patients with tinnitus. Studies[17,18] on the effectiveness of AT also indicate significant results. In addition, a statistically significant reduction in the discomfort caused by tinnitus is observed in elderly hearing aid users after the application of AT, using THI as an assessment measure[18].

In this sense, the development of specialized mobile applications for tinnitus treatment, such as Avazum[5], which assists in the initial screening and assessment of tinnitus and provides guidance and referrals to patients, highlights the importance of integrating detailed assessments and collaborative practices with health professionals. Zumit follows this same line, offering a free tool for assessment and intervention, and aims to be validated by speech-language pathologists and audiologists and tinnitus patients regarding its content, usability and therapeutic impact.

Zumit stands out from other apps on the market because of its integrated approach, which goes beyond simple sound masking. While many apps focus solely on providing temporary relief from tinnitus, Zumit offers a comprehensive assessment and intervention tool, developed under the supervision of speech-language pathologists and audiologists. The use of validated instruments, such as THI and VAS, to assess the discomfort caused by tinnitus, combined with the inclusion of an auditory training program, sets Zumit apart as a robust therapeutic tool. In addition, usability is optimized by the intuitive interface, which encourages ongoing user engagement, while the monitoring of a professional ensures that the intervention is tailored to the individual needs of each patient.

CONCLUSION

The development of mobile health applications has proven to be a promising strategy for expanding access to interventions and monitoring symptoms, such as tinnitus. This study presented the development of a free mobile application, Zumit, intended for the evaluation and intervention of patients with tinnitus. The integration of tools such as THI, VAS, and acuphenometry in the application may support a personalized assessment of the discomfort caused by tinnitus, promoting a more targeted and effective treatment. Zumit stands out for allowing both self-management and direct interaction with the audiologist, ensuring qualified monitoring adapted to individual needs. Zumit offers an innovative and accessible solution for the management of tinnitus, with the potential for widespread adoption in clinical practice. Future studies will be needed to validate the efficacy of the application and evaluate its long-term therapeutic impact in different patient populations. During the present study, relevant questions, that can be explored in future research, emerged. In addition, it is important to explore the integration of the application in multidisciplinary care strategies, such as combined use with behavioral therapies and hearing devices, to evaluate its potential to promote well-being more comprehensively. Research that does not use Zumit but investigates the effectiveness of digital interventions in the management of tinnitus, can also contribute to the understanding of the impacts of technological solutions in the treatment of this condition.

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