EAR: Mobile Solution and Integrated Data Analysis Framework as a Proposal for Monitoring Hearing Loss

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Abstract.

People usually do not give proper attention to their hearing care. The hearing assessment usually occurs as an effect of a nuisance which motivates the person to search for professional treatment. Based on this, the present research demonstrates a mobile application aimed at assisting otolaryngology, capable of measuring levels of deafness of users through sound tests at different levels of decibels and determining whether the environment in which the user is being is harmful to their hearing. During the research, a solution was developed with the association of mobile and cloud computing technologies on a prototype implementation. Experiments were carried out and they demonstrated the ability to collect data on hearing capability on the following frequencies 65, 100, 500, 1K, 5K, 10K and 14KHz. Experiments on how the tool worked at different times of the day were carried out, with evaluations of the best results for each ear of the user. The feature of the tool to manage hearing was verified, both by the doctor and the user, on the hearing capability. The proposed structure proved to be able to receive optimizations based on Machine Learning for issues relevant to the medical field.

Keywords: Otorhinolaryngology, EAR, Cloud Computing, Mobile Solution, Deafness.

1. Introduction

There are several causes for hearing loss, including: excessive exposure to noise, acoustic trauma, aging, sensorineural and conductive (Pynnonen & Schmalbach, 2019). According to the same authors, noise-induced hearing loss is a progressive reduction in hearing acuity due to prolonged exposure and, of lesser intensity, continuously to high levels of sound pressure.

Hearing loss caused by acoustic trauma is caused by an abrupt sound of great intensity. Sensorineural hearing loss is caused by damage to the inner ear or damage to the vestibulocochlear nerve. Conductive loss is due to a hemotympanum, tympanic perforation, or ossicular chain disjunction. Presbycusis, on the other hand, is the active sensorineural loss of the elderly, which is bilateral, of a progressive nature that occurs due to physiological aging. This is because there is a reduction in cellular proteins, pigment accumulations and insoluble compounds in the cytoplasm. Being the most frequent cause of hearing loss in the elderly.

In parallel to this scenario, mobile technologies have been increasingly absorbed as tools to aid the processes of Medicine, whether to assist in an exam, or to manage inventories, in addition to other capabilities (Batista et al., 2020).

With this background, this article aims to create a mobile application that can raise awareness about hearing loss, detecting damage early through the quantification of decibels, advising on the topic and facilitating diagnosis, helping professionals capable of performing interventions, as speech therapists and otolaryngologists. This application will work through the emission of noises of different frequencies, in which the user must demonstrate at what moment he started to hear certain sounds, thus detecting if there was a change in their hearing capacity. As well, the application, through its decibel meter, will be able to determine if the environment in which the user finds themselves is being harmful to their hearing. This work is justified by the consecutive alarming studies on hearing loss at different ages and scenarios such as work, study or leisure environments (Davatz, 2019).

2. Evaluation of Related Work

Research was carried out in the scientific community to verify the state-of-the-art related to the topic of the present work. Although this work presents ideas that are similar to the state-of-the-art, it also adds important features that is discussed in the next sections.

Zhao et al. (2019) made a study that consisted of collecting audiometric and noise exposure data in a population of workers from 17 factories located in Zhejiang province, in China. For each subject in this study, hearing loss was assessed according to the China National Institute of Occupational Safety and Health definition of hearing impairment. However, this research covers the population in general, which means that, the individual user will not obtain an exclusive report, with routine tests and without the possibility of a professional being able to uniquely analyze the data related to an specific user and thus diagnose and recommend a possible treatment.

According to Oliveira et al. (2019), occupational noise in business environments is one of the main unhealthy agents. Premature knowledge of the disability is important, as adequate follow-up delays the progression of hearing loss. Through the EAR, using various sound frequencies, it is possible to identify hearing impairment in people of any age. The EAR provides information centralized in a single application, requiring only a smartphone and internet connection.

3. Theoretical foundations

3.1 Hearing Loss

Hearing loss is a common chronic condition of a disability that affects many people around the world. The influence of risk factors on the degree and rate of hearing loss deterioration includes aging, genetic susceptibility, exposure to ototoxic drugs, ontological disorders, smoking and occupational exposure and leisure noise (Uppala et al., 2017).

It has a variable etiology, which can be genetic, environmental, or both. It can be classified as conductive hearing loss (involvement of the outer or middle ear), sensorineural (involvement of the cochlea or neuronal bundles) or mixed (Barbosa et al., 2018). Intense sounds are transmitted through the ossicular system to the central nervous system. Contraction of the stapedius tensor muscles of the eardrum occurs. The tensor tympani muscle pulls the malleus handle inward, while the stapedius muscle pulls the stapes outward. As a result, the entire ossicular system develops increased rigidity, greatly reducing the ossicular conduction of low-frequency sound. This attenuation reflex can reduce the intensity of transmission of low-frequency sound. This mechanism is believed to have a dual function, as it protects the cochlea from excessively intense sound vibrations and masks low-frequency sounds in intense sound environments. In addition, these muscles decrease the auditory sensitivity of a person to their own speech.

According to the Brazilian Federal Council of Speech Therapy (*Conselho Federal de Fonoaudiologia – Brazil*) (2013), to monitor hearing loss there is the audiometry analysis, which can be divided into tonal and vocal. Tonal audiometry analyzes responses to different sound frequencies, allowing the determination of the hearing threshold of the patient and the component responsible for the loss. Voice audiometry or speech audiometry, assesses the detection and recognition of human speech. Another extremely important test is the immitanciometry, which assesses the functioning of the structures of the auditory system. It is divided into tympanometry, which assesses the tympanic, ossicle and middle ear pressure changes, and the acoustic reflex, which assesses the stapedial reflex and nervous changes. There is also the little ear test, which is recommended for all newborns. The evoked otoacoustic emissions (EOA) were evaluated through responses generated by the outer hair cells of the cochlea, in order to identify congenital cochlear lesions.

Normal hearing has thresholds between 0 and 24 dB hearing level (HL). Mild hearing loss has thresholds between 26 to 40 dBHL. Moderate hearing loss has thresholds between 56 to 70 dBHL. Moderately severe hearing loss has thresholds between 71 to 90 dBHL. On the other hand, profound hearing loss has thresholds greater than or equal to 91 dBHL.

3.2 Information Technology Concepts

The concepts associated with information technology, Cloud Computing and Technologies applied to the development of mobile solutions were used as the basis for such research. According to Hussein and Khalid (2016), Cloud Computing is a model that allows ubiquitous, convenient and on-demand access to a shared set of configurable computing resources such as: networks, servers, storage, applications and services, which can be made available with a minimum managerial and iterative effort with the service provider.

Regarding the mobile solutions and technologies, JavaScript, React Native and Node.js were used to develop the programming part of the solution and Firebase Realtime Database was used for the data consolidation part (Hoque, 2020). The interaction between such technologies is the premise of the EAR platform developed in this article.

4. Methodology

The methodology of this research is considered of an experimental type, where a solution in prototype format was developed and its functionality verified. At first, a study of the human capacity of auditory perception was carried out based on the degree of decibels and the levels considered normal and critical for hearing. After this step, it was possible to carry out a few tests with technical support to determine the levels of hearing impairment in users.

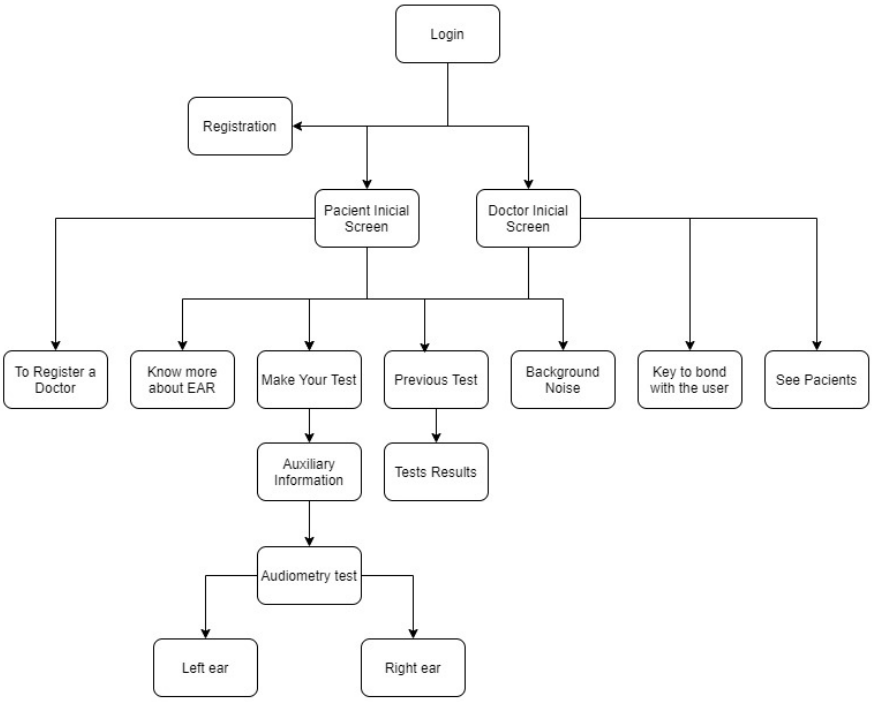
The development was based on mobile devices, in order to reach a large portion of the population, since it is common nowadays for people to be in possession of some mobile device. The choice of technologies used in the project was based on the practicality of JavaScript development, along with the dynamism of Firebase platform in data storage and the flexibility of React Native in converting to various platforms such as Android and IOS without the need for programming in native languages of the respective technologies. At the end of the development of the first version, a collection was carried out for a pre-analysis of the auditory data of the users who performed the tests present in the application.

5. Results

5.1 Mobile Structure

A mobile application was developed and validated, through audiometric tests, to indicate the degree of hearing impairment of the user. Thus, the requirements related to the work process of the app were carried out, by identifying the agents and their respective functions in the process. Two agents were defined, the Patient being the requesting agent who will carry out the audiometric tests and the Physician, who is able to monitor their Patients, and can visualize the progress of the tests performed. In Figure 1, the application structure diagram is displayed.

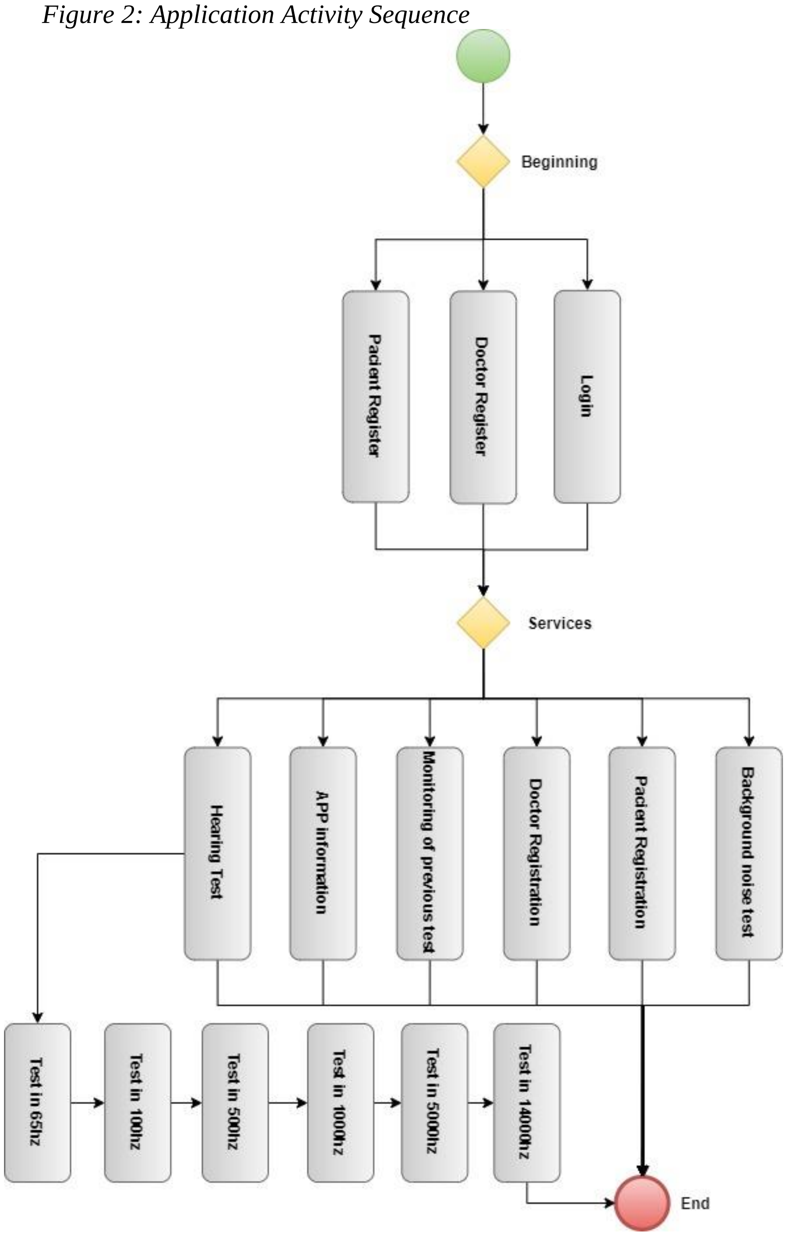
Figure 1: Application structure diagram



Source: Authors, 2021.

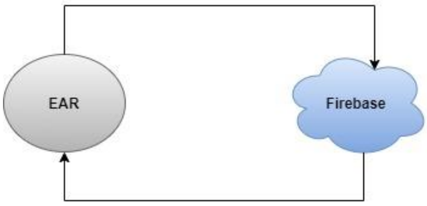
When using the application, depending on the profile of the user, they have the option to better understand the purpose of the project and its real importance, perform the hearing tests that can later be monitored in some dashboards, register a doctor so that professional monitoring is possible and test for ambient noise. In Figure 2, the sequence of activities available to the user is shown, which must be performed by the application. The operation of the application consists of registering the user in the database by selecting a profile, whether this is a patient or a doctor. A patient can undergo hearing tests in which they will be subjected to noise at specific frequencies and decibels, where at the end of the test a report will be created. When a patient is linked to a doctor, the tests can be monitored by the professional, thus aiding in the diagnosis. The application can also help in the prevention of hearing loss, where the user can use the noise analyzer to get a knowledge of the current environment. Figure 3 demonstrates the flow of communication between the technologies used by the application. The EAR app requests or inserts information into Firebase, which in turn responds to the requests. In Tables 1 and 2 the application screens are shown.

Figure 2: Application Activity Sequence



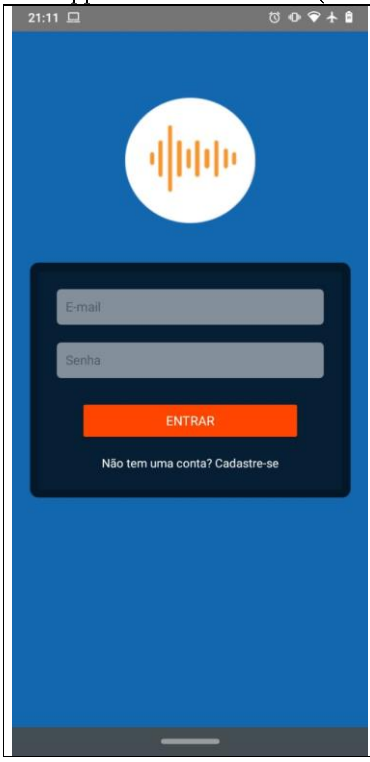
Source: Authors, 2021.

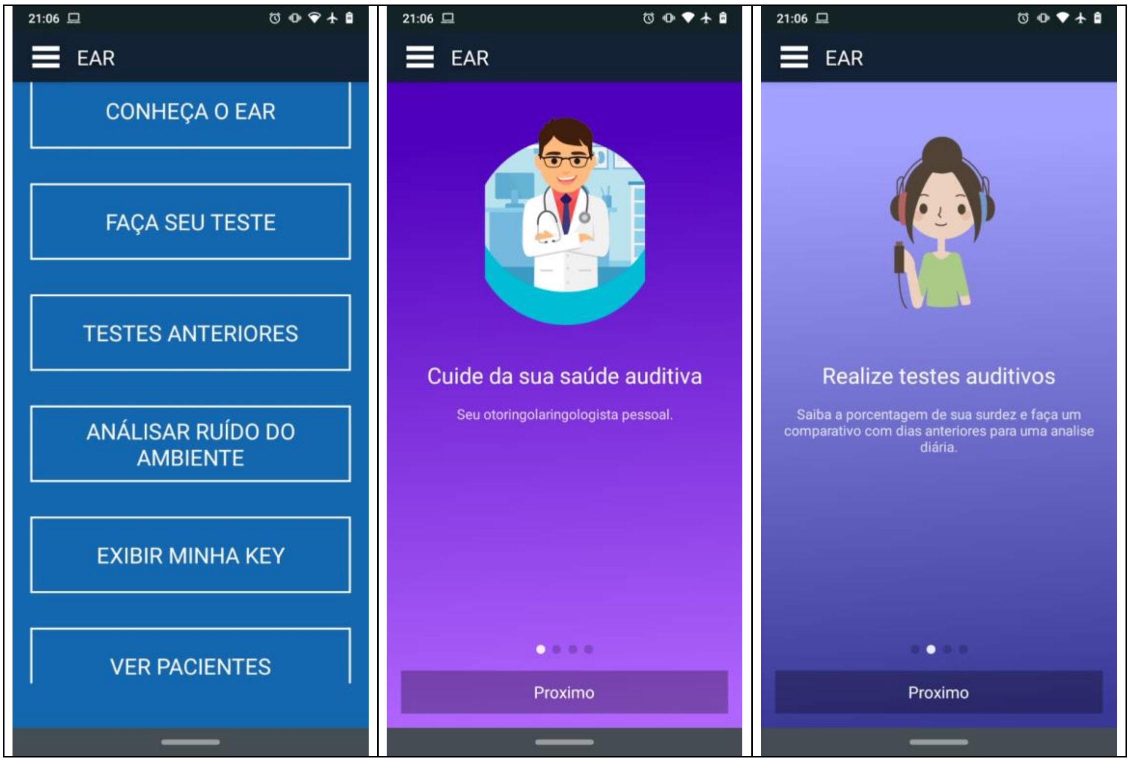
Figure 3: Mobile application infrastructure



Source: Authors, 2021.

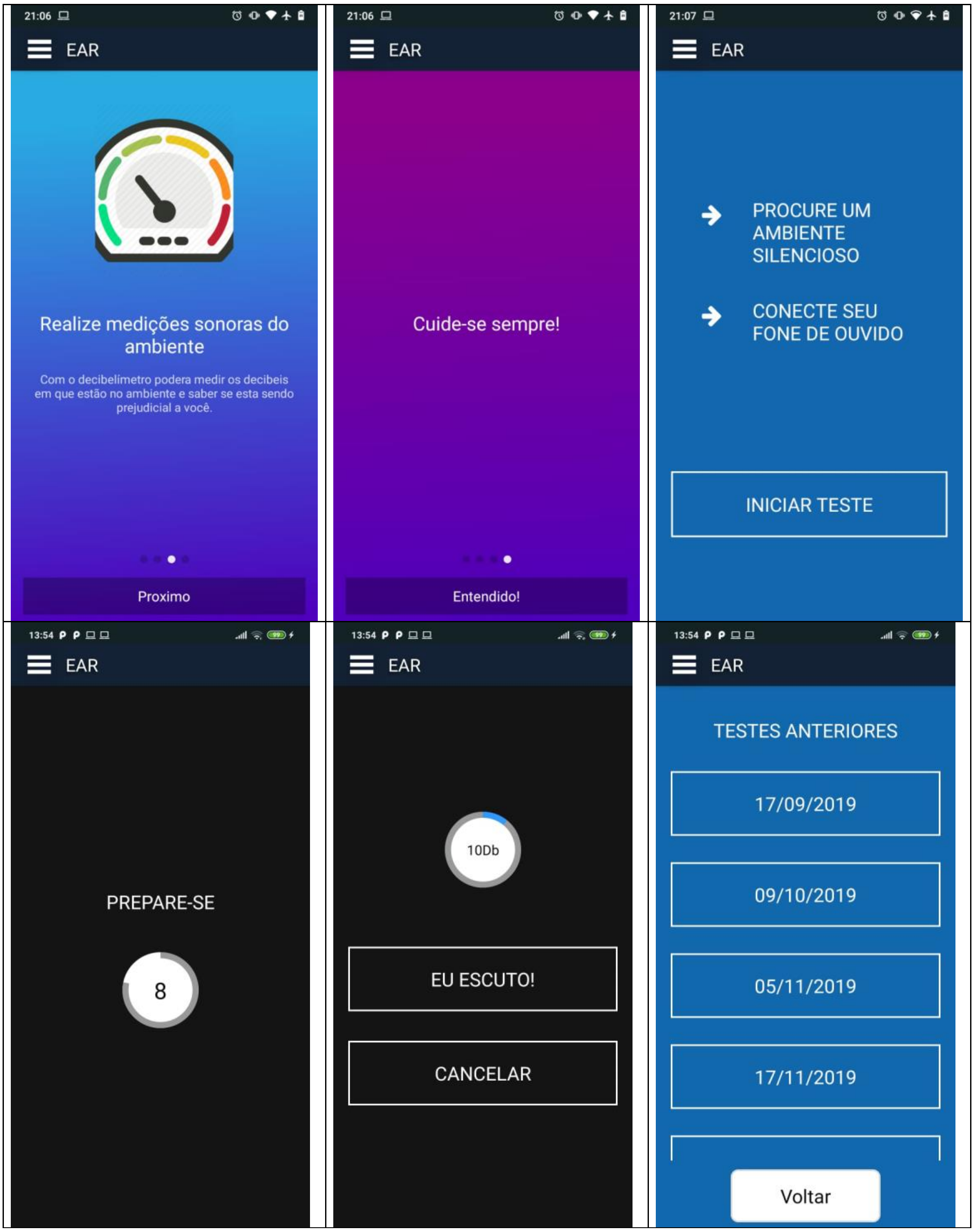
Table 1: Application screenshots (Part 1)





Source: Authors, 2021.

Table 2: Application screenshots (Part 2)

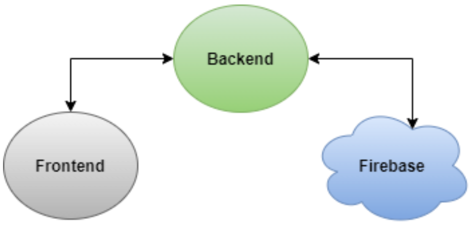


Source: Authors, 2021.

5.2 Data Analytics

A web application was developed in order to use data analytics to present the data collected in the tests performed by the user on the mobile application. Figure 4 demonstrates the communication flow between the technologies used by the web application (Frontend), where the client requests the information that will be processed by the intermediary application (Backend), that collects the data in Firebase, and returns the requested information for presentation in form of Dashboards to the Web client.

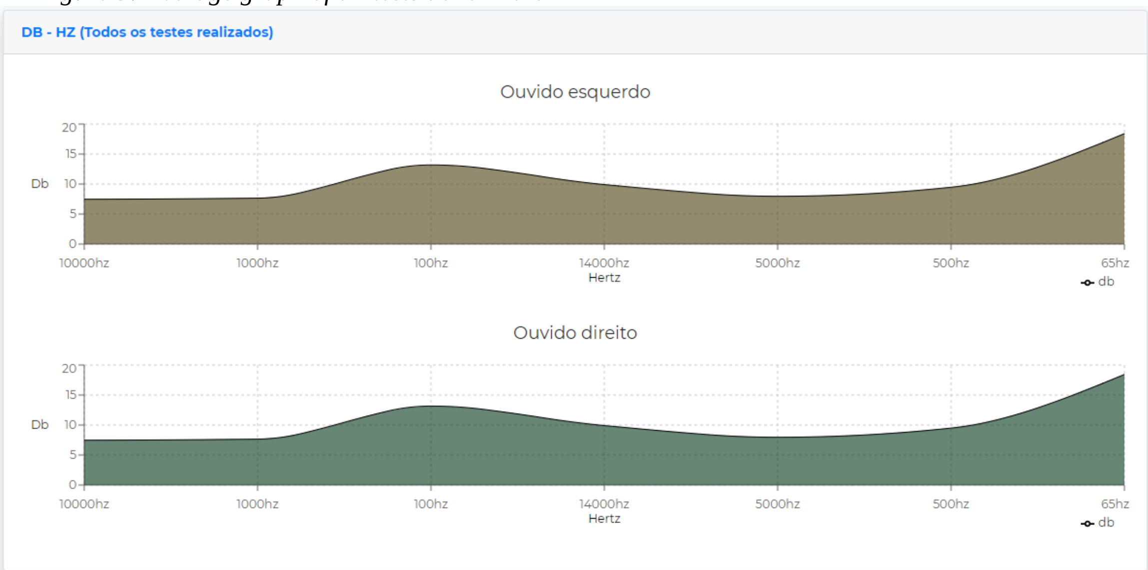
Figure 4: Web application infrastructure



Source: Authors, 2021.

Through dashboards it is possible to obtain strategic analysis of the user data. Figure 5 shows the average of all tests performed in the EAR app, showing the average per ear. Thus, it is possible to observe the hearing quality of the population, compare the result between the ears, determine the degree of auditory stress of users or identify the less noticeable frequencies.

Figure 5: Average graph of all tests done in the EAR



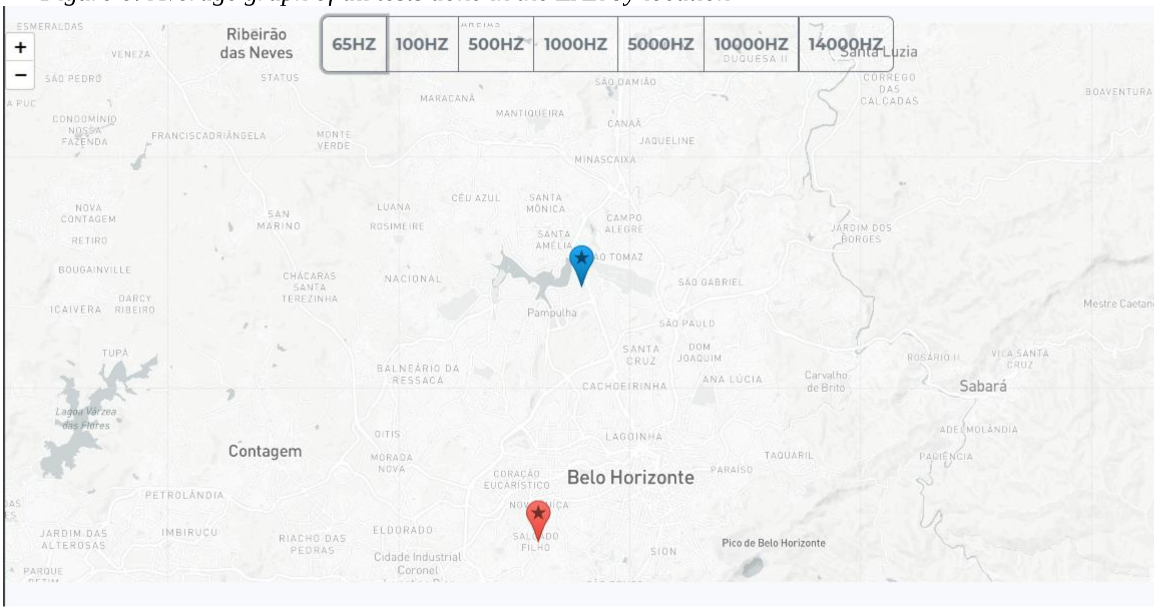
Source: Authors, 2021.

Figure 6 demonstrates the average analysis of all tests performed in the EAR application, through the map. It is possible to observe the places where the audiometry tests of the user were performed, showing the areas that obtained the highest and lowest average of Decibels with the test results. It is possible to verify places where there is greater auditory stress, and it is also possible to observe the regions with the lowest averages for each frequency of the tests.

Figure 7 shows the patient list of a doctor, where one or several users can be selected. From this selection, all tests for the selected users are grouped by time of completion. After grouping, the average decibels per hour is calculated. Figure 8 demonstrates the average minimum and maximum decibels per hour indicators for each ear. The lowest average is the best result, as it indicates that the user quickly identified the sound emitted by the application. In addition to the indicators that show only the highest and lowest average per ear, the average

of all times can also be observed through the average graph of decibels per hour. Such analysis is important to identify the best and worst times for testing.

Figure 6: Average graph of all tests done in the EAR by location



Source: Authors, 2021.

Figure 7: Doctor's Patient List


Visualizar Resultados do Grupo

#	Nome	Selecionar
0	Sofia Vilela Soares	■
1	Brenda Meireles	■

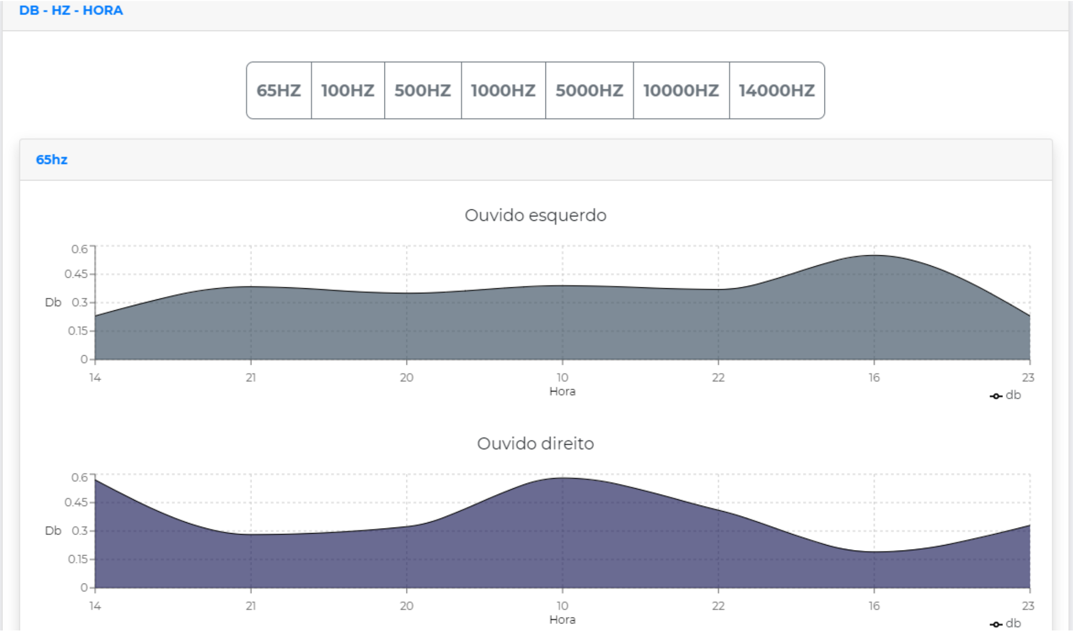
Source: Authors, 2021.

Figure 8: Minimum and maximum average decibels per hour indicators

Source: Authors, 2021.

Figure 9 demonstrates the consolidation of tests performed by the patient in the EAR mobile app. The analysis is made based on the selected frequency, where the average of decibels obtained during the hearing test is calculated. This average is crossed with the hours in which the tests were performed and thus a variation of the hearing capability of the user can be observed according to the time of day.

Figure 9: Decibel indicators by patient hourly frequency



Source: Authors, 2021.

5.3 Comparison with Current Technologies

The main differentials of the EAR app related to the state-of-the-art are: the possibility for the user to link their doctor to their account; the doctor can monitor the analysis of one or more patients in isolation or together; it is possible to observe the places of performance of the highest and lowest user performance, being able to view the result of a frequency individually. In addition to these elements, the solution includes compliance with the LGPD. According to the LGPD, users can send a unique access key to the doctor, from which the doctor creates a link with the patient. At any time, the user has the possibility to unlink the doctor, removing the access of the doctor to the data of the user.

Finally, some feasibility was achieved. The mobile application has a simplified layout, providing greater accessibility for all users. From the mobile application it is possible to perform audiometry tests, observe the results from graphs and create a link between the patient's doctor. The generated data is stored in the cloud, increasing the practicality due to the instantaneous access to the information, providing reliability and security. Through the WEB application, professionals can analyze the data of their patients individually or collectively. It is also possible to observe the results according to each frequency that the patient was submitted.

The professional can observe through a map, the locations where the patients obtained the highest and lowest performances. From this view, it is possible to identify the locations of potential harmful to the health of the patient in the long term. These data enable professionals to perform pre-analysis, enabling knowledge of new variables that contribute to hearing loss. Over time, work can be carried out to minimize the number of people affected by these detected variables.

5.4 Future Studies

The next steps to be followed after the completion of this project are the implementation of resources that maximize the assertiveness of the analyzes obtained through the EAR database. Such features are:

- Machine Learning: to enable assertive analysis through complex calculations and various comparisons.
- Predicting Hearing Loss: With the complete database, clinicians will have a baseline for treating hearing loss. Through the mathematical methods applied to the data, it will be possible to observe implicit patterns and associations. Being able to predict the chances of occurrence and the degree of future hearing loss in a given population.
- Predicting consultation demands: By analyzing the tests performed by the user and by quantifying the data, it will be recommended to look for a specialist for a face-to-face consultation and follow-up.

The feasibility of these experiments depends on the volume of data generated by the application. Adding new users increases the amount of data generated and the diversity needed to detect different scenarios.

6. Conclusion

The present work has the capacity to contribute epidemiologically to the detection and quantification of the number of individuals with hearing loss and the qualification of this loss. The analysis of hearing loss according to age, sex and profession was made possible. Therefore, it will be possible to interpret the influence of everyday noise on the quality of life of users. There is also the possibility of the evolution of the routine of the user after using the application. Also of great importance is the early detection and professional intervention, in order to minimize the damage caused by already installed hearing loss and future losses.

Epidemiology can also be addressed in future studies, through the quantification of users that exceed the daily limit of decibels. Thus, the number of individuals who need a specialized team capable of performing effective interventions would be identified. From this, it is possible to achieve a reduction in the number of cases of hearing deficits that are preventable, for example, through a few simple guidelines to the entire population. Furthermore, it is necessary that, from the evaluation made in the application, the user feels motivated to look for a professional specialized in this area of health in order to verify if there really is any level of hearing loss. Thus, it is contacted that it is a promising tool for medicinal actions.

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