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A SPIRAL-BASED APPROACH TO THE INTERFACE DEVELOPMENTOF ASSISTED-INTERACTION SOFTWARE FOR DEAF PATIENTS IN DENTAL TREATMENT

The research presents a technological solution to simplify the interaction between dentists and deaf patients. A key element in this case is communication and the obstacles that can lead to social or health problems in which the patient gives up completely on seeking treatment. Apart from the theoretical studies on the subject, it was carried out an empirical and analytical research, starting with a field investigation and the creation of the dental related terms for the Brazilian Sign Language (LIBRAS) by a team of specialists. Followed by the establishment of a software development model, based on SE Spiral model, which helped to design the user interface and its usability heuristics analysis.

Keywords: Assistive Technology, UX/UI Design, Deafness, Dental Care, Interface Development Model.

MODELO ESPIRAL NO DESENVOLVIMENTO DE INTERFACE EM SOFTWARE DE INTERAÇÃO ASSISTIDA PARA PACIENTES SURDOS EM TRATAMENTOS ODONTOLÓGICOS

A pesquisa apresenta uma solução tecnológica para simplificar a interação entre dentistas e pacientes surdos. O problema central abordado é o fato de que a falha na comunicação neste contexto pode gerar estigmas sociais e riscos para a saúde do paciente que por muitas vezes desiste completamente de procurar tratamento. Além de estudos teóricos acerca do tema, foram realizadas pesquisas empíricas e analíticas. Seguido de uma investigação de campo e criação de termos odontológicos (até então inexistentes) na língua de sinais brasileira, por um time de especialistas, seguido da definição de um modelo de construção baseado no modelo SE espiral que guiou o processo de design da interface do usuário e as avaliações heurísticas.

Palavras-chave: Tecnologia Assistiva, UX/UI Design, Surdez, Modelo de Desenvolvimento de Interface.

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1. INTRODUCTION

Communication is a primordial element in human interaction. It is the only way possible for people to transmit complex ideas, feelings and emotions that leads individuals to dialogue, seek solutions and build meaningful experiences as a group.

In this sense, communication stands as the cornerstone of the modern world, especially in the information era. Society in return must adjust the means through which people communicate. Provide the individuals involved in the process with any tools necessary, taking into account the various limitations of certain people. Even with the advancement of assistive technologies and accessibility laws, there are still many groups that are excluded. Among these and the main theme of this research are the hearing impaired people that have their ability to communicate hindered by the lack of access to the linguistic code, oral and written, and consequently do not extract meanings from it.

Relying only on the visual-gestural method of communication, provided by a sign language scarcely known by a large part of society, this limitation poses as a challenge to the hearing impaired, turning apparently simple interactions into complex and frustrating experiences for both parties, resulting in social isolation.

Communication in any health care scenario is a vital condition for the quality of services provided; also it helps establish a solid professional-patient relationship, without the assistance of an interpreter. Thus the problem emerges: How to set up a model of software-assisted interaction that efficiently simplifies the communication between the Dentist and the hearing impaired patient? A model of software- assisted interaction for dental care is a valuable and adapt- able tool that could be implemented in other countries. Other sign languages, such as the American Sign Language (ASL) have a distinct syntax and grammar of oral languages and presents similar challenges. The amount of countries that would benefit from such software can be seen by the number of ASL speakers in Canada, Mexico, Philippines, Singapore, Hong Kong, the Dominican Republic, Haiti, Côte d'Ivoire, Burkina Faso, Ghana, Togo, Benin, Nigeria, Chad, Gabon, Central African Republic, Mauritania, Kenya, Madagascar and Zimbabwe (Hochman, 2000).

The research counts with the collaboration of Sign Language specialists, Computer Scientists, UX/UI Design professionals and Dental Studies researchers.

2. BACKGROUND AND OVERVIEW

The level of comprehension of a language is considered a status certificate that separates people into different social and cultural groups. Therefore, for hearing impaired people to lack such skill can be a synonym of shame and to be put in an inferior position. The effect of this stigma and prejudice, results in feelings of incapacity and a fear of how they are perceived by others (Botelho, 2002).

Gestural languages are present in the five continents, how- ever far from being a universal language, since each has its own structure (Allen, Meyers, Sullivan & Sullivan, 2002). Even with the possibility to express any complex term using sign language, the obstacle to individuals speaking different languages, still keeps hearing

impaired people and listeners from interacting.

The Brazilian sign language (LIBRAS) has its origin in the French Sign Language, and is now recognized by Federal Law regulated on December 22nd, 2005, as a means of communication for the deaf community (Chaveiro et al., 2010).

However, society does not offer the hearing impaired fair conditions to develop their language. So we can discard the idea that deafness is the cause of all these problems, since the real cause lies in the conditions offered by society. It is vital to take action and provide scenarios where these individuals can articulate ideas with their own tools, rather than only make the sign language official and impose actions by accessibility laws.

2.1 Health Care for the Hearing Impaired

A study conducted in 2006 with hearing impaired people, indicates the reasons that led these people to seek medical treatment. The results showed that the demand for dental treatments is among the main reasons, and the greatest obstacles are the professional's lack of preparation and tools to assist in the care of deaf patients (Cardoso, Rodrigues & Bachion, 2006). All deaf patients ex- pressed their despair regarding their interactions with doc- tors and nurses (Witte & Kuzel, 2000).

Another research created a list of recommendations to improve accessibility in health care service, which are: talk slowly (articulate), look at the patient in a well-lit room; avoid complicated terms or complex sentences; avoid masks, hands, mustaches and beards; use gestures; emphasize facial expression; use illustration with texts to avoid confusion; provide explanations before, during and after performing any procedure (Costa et al., 2009)

It is often thought that the assistance of interpreters in these situations would be a solution to the problem. However, it is not enough to know sign language, it is also necessary to respect secrecy and know how to transmit the content of the message (Chaveiro & Barbosa, 2005). In the health area there are many specific terms and technical language, which often do not exist or are not accessible to interpreters that do not deal with health issues.

2.2 Usability Heuristics

Usability's purpose is to strengthen the bond between humanity and technology, by making it easier and more enjoyable (Nielsen, 2007). To develop a system, it is necessary to study in detail the relations that occur between the user and the soft- ware, as well as to predict all kinds of interference that they may have from the surroundings in which they integrate. The criteria used to evaluate or develop an interactive system are described by several usability specialists. Among these are those indicated in this research.

The heuristic evaluation method has ten recommendations elaborated by Nielsen (1994) which are: Visibility of system status, match between system and the real world, user control and freedom, consistency and standards, error prevention, recognition rather than recall, flexibility and efficiency of use, aesthetic and minimalist design, Help users recognize, diagnose, and recover from errors, and help and documentation.

With regard to UI design Shneiderman et at. (2016) point out eight golden rules, these are: strive for consistency, enable frequent users to use shortcuts, offer informative feedback, design dialog to yield closure, offer simple error handling, permit easy reversal of actions, support internal locus of control, reduce short-term memory load.

Nielsen's heuristics and Shneiderman's golden rules have some similarities. Both seek the best user experience, quality and accessibility of the interface, based on the user-friendly interaction and usability of the system.

2.3 Digital Accessibility

While Universal design addresses the design of products for everyone; accessible design is concerned with helping people with limitations or disabilities (Dias, 2007). In the digital context, accessibility is connected to the ability of software to be used by people with special needs, even if the steps of interaction are not the same.

Digital accessibility should be seen as the ability to access with autonomy any computer system, regardless of the user's sensory, linguistic and physical condition (Corradi, 2007). Therefore, the obstacles that hinder the access to information are directly related to the absence of accessibility and the inadequate treatment of information.

Software, websites or any hypermedia that makes use of audiovisual resources and that do not offer a subtitle option, reinforce barriers for the hearing impaired. In addition to subtitles, there are alternatives seen in table 1 that can be employed to minimize the difficulty to access such media.

Table 1: Assistive Technologies for Hearing Impairment

Tools	Function
Subtitle	Adds text to ambient, sounds, words spoken or sung in videos
Sound Notification	Visual representation of sounds, from signals to alert or error messages.
Sign Language Translation	Visual translation in sign language of dialogues, actions and ambient noises.

Source: Dias (2007)

2.4 Human Computer Interaction - HCI

The evolution of technology makes it clear the intention of hiding its coded and "cold" machined core through inter- faces. These interfaces operate in the same way as a skin: a reactive element between information, action and processing. This can be seen through the evolution of command line interfaces (CLI) to graphic user interfaces (GUI) and finally, today, the touchscreen interaction that generated a new interface model called Natural User Interface (NUI).

Following the idea of the interface as a skin, the GUIs would be as something synthetic, a makeup applied to software. The NUIs extrapolate these barriers; they do not mask the program, but integrate it completely (Wigdor & Wixon, 2010). It reduces computing barriers further, while simultaneously increasing user power and control. So an interface is Natural if it takes into account existing user skills, not only the ones are innate to a large majority, but also those that have been learned and

mastered through prior technologies (Wigdor & Wixon, 2011)..

In this sense, it is required to explore patterns and standards related to interaction and navigation, since those are the basis of a good user experience. In relation to navigation we can search current trends of big software companies, how they display information, as well as aesthetic options currently adopted.

UI design patterns are reusable solutions to recurring problems of interaction and interface; it is not a template that can be placed inside a product and not even the finished design of it (Bank & Pacholkzyc, 2014). They are best practices formalized in guides and examples that can be used by designers, developers, and managers to solve common problems encountered in developing an application.

What the trend shows are that speed, efficiency and effectiveness, aligned with new forms of interaction supported by the hardware, all aligned with a good layout design is a good start point for any app developer.

2.5 Spiral Model

The Spiral model for software development was proposed in 1988, by Boehm (1988) and it is one of the first models to propose the incremental development. The model can adapt activities provided from other methods to the products that will be developed.

The model is focused on an incremental development, proposing a cyclic process, oriented to prototypes and provides a very good risk management approach, whereas with the incremental and evolutionary development, the organization can evaluate results at each iteration and it is possible to identify risks and repair the product more effectively.

The main contribution of the spiral model is to direct the development process based on the management and control of project risks and also on the constant re-planning of actions.

3. METHODOLOGY

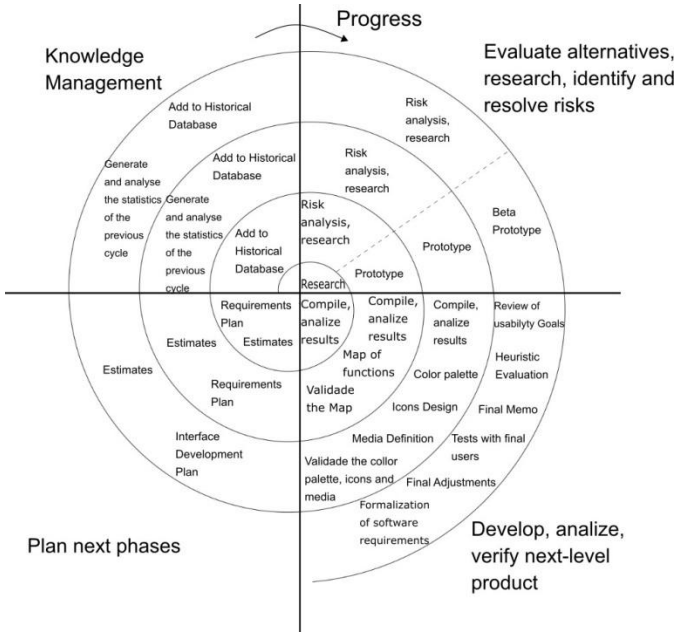
This is a research of an applied nature, after all, the problem will be completely mapped, resulting in the development of the interactive application/platform, and also it has an exploratory dimension, which will establish techniques and aims to offer information about the subject and guide to the resolution of the problem (Bervian, Cervo & Silva, 2002).

For that, we applied an approach based on the Spiral model for software development, which allowed a faster, efficient and safe design process and requirements definition, since no staff member had any prior knowledge of how to develop software or develop an interface for the hearing impaired patients.

3.1 Proposed Model

The proposed model, presented in Figure 1, presents an approach to the spiral model (Boehm, 1988) focused on the analysis of requirements and also to the development and prototyping of the final user interface minimizing the risks, since the hearing impaired has his communication capacity compromised due to lack of access to the language, oral and written.

Figure 1: Proposed Model



Source: Boehm (1988)

The main objective of the proposed approach is to allow the collection of requirements and the interface design, oriented to prototypes, speeding up the design process. It is indicated mainly when the development team has no previous experience with the type of tool and also with the target user of the software project, as it allows the team an iterative and continuous interface development process, always giving priority to the user's needs and the characteristics of the software. Another important point to be highlighted is the risk management, adapted from the spiral model, which at each iteration makes an analysis of the inherent risks of the project, as well as research to support the development of the artifacts of the next iteration, thus developing the functional prototype that will be validated with the team specialists.

The cycle of the proposed model begins with a research on the main problem, the user and also similar software's present in the market. This step is very important because it allows the team to understand the problem and immerse it in the user's world, allowing a greater understanding of their needs. From this, the next step is to compile and analyze the collected data and then plan the requirements.

The next phase, comprehend the analysis of risks; research and the development of the initial prototype, that should al- ready contain a sketch of how the interface must be. In the next step, the data generated in the previous step is compiled and analyzed, as well as the generation and validation of the application's function map. Here we have a critical phase of the project, because all subsequent steps will be done based on the function map that will be produced here. This step

should take special care of the developers and should be done by both design and computer professionals, since if done in this way, besides the function map, software requirements are also generated.

The next steps include requirements planning, risk analysis, research and the development of the new prototype. After that, the data is analyzed and then the color palette, the icons, the definition of the media and their validation. Here it is strongly recommended that computer professionals and design professionals work in an integrated way, ensuring that the proposed design can be implemented.

The next steps are planning interface development, risk analysis and development of the Beta prototype. Here we al- ready have a functional interface prototype that can already have its usability tested by specialists and users.

The next steps consist of a usability review, expert heuristic evaluation, end-user testing, correction of the final interface based on the users test results, final design memo, and formalization of software requirements collected throughout the project. Here, the team already has all the final interface design and also the formalized requirements, being able to develop the software with any other development methodology.

Knowledge management is performed after each planning phase. The data from the previous cycles are compiled, analyzed and then added to the historical database.

The main focus of this work was developing a prototype of software that can be used in the hearing impaired patients. Because of that, and based in the previous information that the hearing impaired people have some difficulties for communicate, being the interface the primary way for their communication, this work focus on the main part of the development, the interface, and let the software development for future work.

4. PROTOTYPE

4.1 Research

We performed the analysis of similar apps based on Nielsen's usability heuristics. The object of study is two sign- language translators, the ProDeaf and Handtalk. In general, they are a set of software capable of translating text and voice from Portuguese to Brazilian Sign Language. The interface is quite simple and offers no obstacle to use. For beginners, a tutorial in Portuguese explains all the features offered by the application.

The pros and cons as well as the main features of the apps are: With each action the application there is a visual response to what function is being performed, use of simple terminologies, the lack of images representing the words poses as an obstacles for deaf people, no options to return or undo actions, good layout and tutorial explaining the functionality, big icons and few actions that can be executed prevent the user from having to memorize paths, creates shortcuts for recently searched words, avoiding repetition of actions, clean interface with minimalist icons, error messages are presented with the solution.

The Apps have a 100% success rate of 8 out of 10 heuristic items. They do not present major interface problem, and the ones noticed can be easily corrected. Since they are well accepted applications on the market, it is relevant to adopt certain HCI

parameters associated with them.

4.2 Concepts, Direction and First Prototypes

Since the development of the application is aimed at the deaf public, which presents difficulties in understanding written language and they have enhanced visual cognition, it will be used for the production of the interface a minimalist language and aesthetics called ”flat design”, followed by its opposite language, the realism, to bring the best of both worlds.

Unlike plain minimalism flat design dictates that graphic elements must be devoid of three-dimensional aspect, complex textures and have an obvious reduction of elements (Duval, 2016). On Figure 2 we can see the two-dimensional aesthetic employed, as well as the reduction of resources in the design of elements.

Figure 2: Flat Design

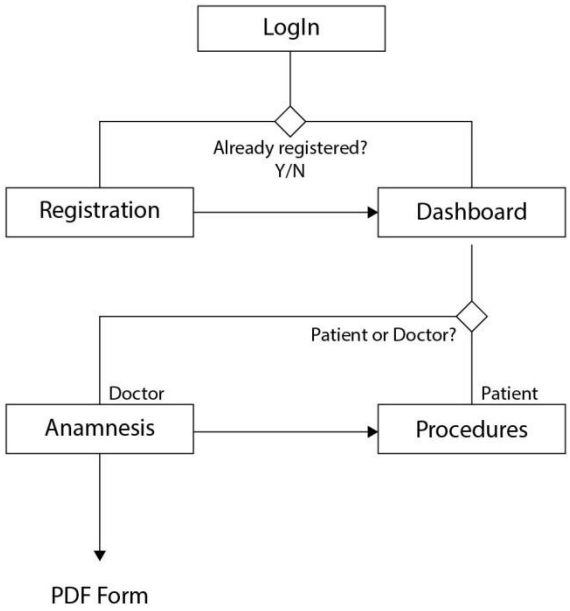
Source: Vector (2015)

Following the idea that a graphic piece can be flat, but not necessarily minimalist, or vice versa, in a discussion held among the research team, it was decided to adopt flat aesthetics, only for interface elements, such as icons. In the illustrations that represent the dental procedures will be used the mix of minimalism with realism, thus reducing the ambiguity seen by the use of minimalism.

4.3 Map of Functions

Before starting to develop the interface, it is necessary to de- fine the map of functions performed by the application. Ac- cording to Figure 3, the external areas of the application, are destined for the user registration and login, followed by the activity dashboard; subdivided between anamnesis (questions about the patient’s condition) and the dental procedures (terms) that will occur during a consultation.

Figure 3: Map of Functions



Source: Author

4.4 Icons, Colors and Media

As mentioned before the illustrations must present a minimalist aspect combined with realism in order to obtain appealing images easy to understand.

The research team decided to represent instruments used during dental procedures more realistically, without the use of minimalism so that there is no confusion between what is drawn and used

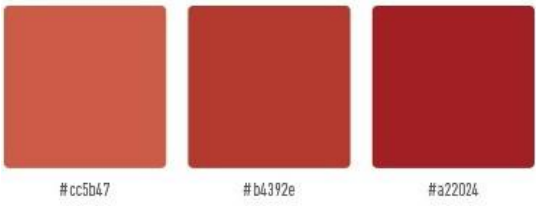
After defining the style of the illustrations, as well as a base image a set of illustrations can be developed for the dental terms defined on the previous research phase. Are they: Braces, Dental Calculus, Third Molar, Dental Abscess, Dental Implant, Floss, Anesthesia, Molding, Floss, Biofilm, To Bite, Toothbrush, Gargling, Orthodontics, Dental Paste, Oral, Palpation, Dental Brushing, Cavities, Clinical Forceps, Oral

Mirror, Scarring, Radiography, Tooth Extraction, Tooth Whitening, Amalgam Filling, Fluorine, Deciduous Teeth, Resin Filling, Gingivitis, Gum Disease, Periodontal Probe, Numb- ness and Surgical Suture.

After that we set up things such as: Typography, Color and Icons. The font chosen is from family Nunito, which will be used for texts in general, because it presents a simple and clean design that contributes to the readability.

The main colors of the app are three shades of red, Figure 4. Red has a strong connection with health care and its energetic quality promotes feelings of trust. To avoid ideas of violence, blood and pain associated with red, white and gray are harmoniously mingled to produce a visually appealing interface.

Figure 4: Shades of Red



Source: Author

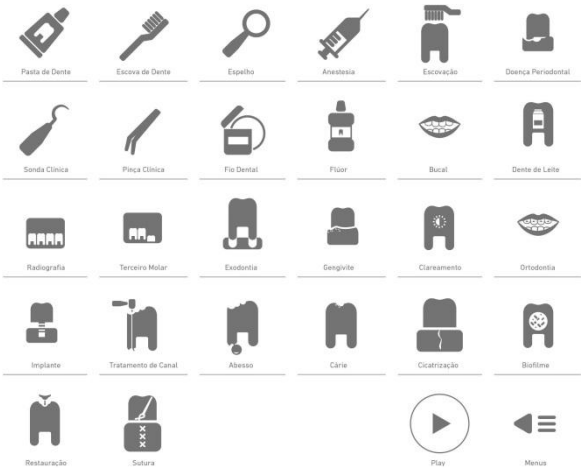
As specified in the concept, icons must be developed in flat design, so in Figure 5 we have the app access icon.

Figure 5: Icon

Source: Author

Only the dashboard icons will be represented in a minimalist style. Figure 6 below contains the main icons developed for the dental procedures menu.

Figure 6: Menu Icons



Source: Author

4.4.1 Recording Dental Terms

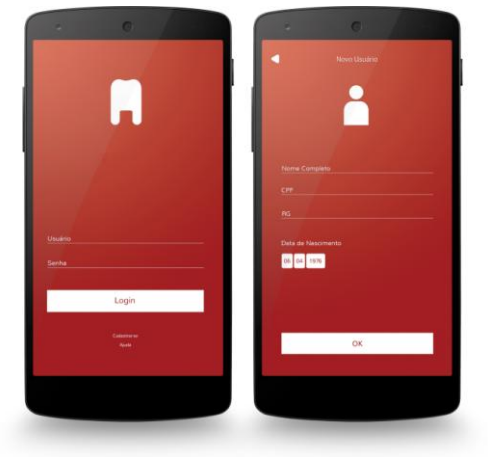
To record the videos with translated terms in sign language, we followed the standards of ABNT (Brazilian Association of Technical Standards) NBR 15290 elaborated on the Brazilian Accessibility Committee. In total of three days were recorded the 34

selected dental terms and 35 questions.

4.5 Beta Prototype

Despite its large amount of content, the application has a small number of elements per screen, thus maintaining spatial cleanliness and clarity is essential for a good usability. Figure 7 shows the login screen and registration, with a very minimalist approach.

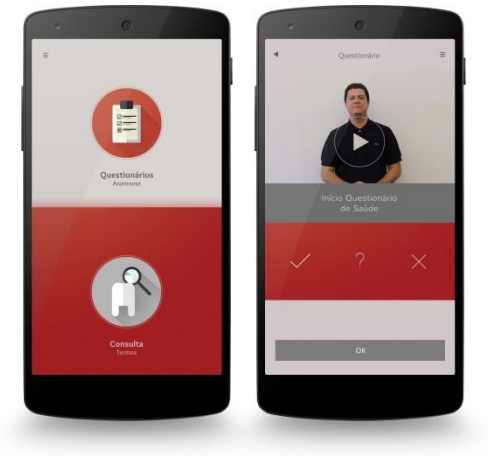
Figure 7: Login and Registration



Source: Author

Figure 8 shows the quick access menu for two main areas: anamnesis (questionnaire) and dental procedures. The clinical questionnaire, Figure 8 (right) presents four basic actions: yes, no, I do not know and next.

Figure 8: Dashboard and Form

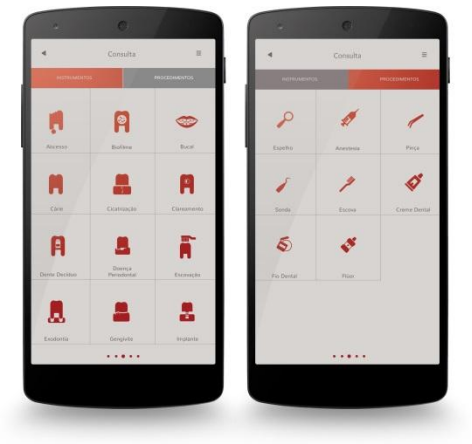


Source: Author

The translation access menu, Figure 9, has visual clarity and the number of

actions reduced by grouping the terms within two categories: clinical instruments and procedures.

Figure 9: Procedures Menu



Source: Author

4.6 Review of Usability Goals

After the development of the beta prototype, internal evaluations and reviews for the interface (by the research team and professionals) are initiated, in order to guarantee the consistency of the goals proposed for this research.

The criteria used to review the app are contained in Table 2, as well as the suggestions made to align the final application with goals and standards defined throughout the research. Information represented by the *d* represents the Dentist's opinion and the *e* represents the usability specialist's analysis.

Table 2: Review of Usability Criteria

Criteria	Y	N	Notes
1 *Hearing Impairment*			
Perception and Cognition: Does the application take into account visual-gestural perception rather than oral-writing?	ed		Some menus have no translation.
Sign Language: Does the app have full translation and access in LIBRAS?	d	e	
Medical Assistance: Meets the requirements for improvement in care seen in Costa et al. (2009)?	ed		
2 *Design*			
Universal Design: Does the application abide by the usability principals to achieve greater user reach in design?	ed		Sign Language, Subtitles and Illustration.
Usability: Does the app follow the 10 usability heuristics?	ed		
Accessibility: Does the interface make use of different forms of communication, to transmit its messages?	ed		
3 *HCI*			
NUIs: Does the app show consistency with the standards of the market?	ed		Some buttons are unreadable (small font).
UI Design Pattern: Is the application up-to-date on new forms of	ed		

interaction (mobile devices) and good aesthetics?		
Typography e Color: Are the colors and fonts used appropriate? Is there any difficulty reading or reading at some point?	d	e

4.7 Heuristics Evaluation

The heuristic evaluation was carried out by five professionals (design and usability), to discuss the efficiency of the interface according to Jacob Nielsen's heuristics. The purpose of this assessment is to get an external view of the application and ensure that future adjustments are based on consistent data. Following are the results of the discussions and evaluations, with their critical points highlighted: 1) Visibility of system status: with each action performed the app informs which function is being executed. However, some deaf users may have difficulty navigating some menus, since they do not know Portuguese very well, 2) Match between system and real world: the app uses video to translate dental terms. Illustrations are extremely effective. 3) User Control: the user can undo actions and back buttons are always accessible. The user has no control when it comes to search dental terms by alphabetical order, 4) Consistency and Standards: The app is efficient; there are no situations where ambiguity occurs, 5) Recognition: Large and visible icons prevent the user from having to memorize where to find a particular option, 6) Error Prevention: requires a tutorial, 7) Minimalist Design: clean interface, with minimalist icons; Nothing competes with important information, 8) User Support: visible error messages presented with a solution.

The collected data show some critical points in the interface that make it difficult for deaf patients to navigate through it. In this way, the correction of these points will be made and recorded in the final results.

4.8 Final Design and Memo

Rules and parameters: 1) Dimensions: responsive layout, 2) OS: iOS, Android and Windows, 3) Devices: Smartphones, Tablets and PC (Future), 4) Offline: The app does not re- quire internet to operate its main functions. The specific characteristics of each screen will be detailed below with the aid of images from the final app.

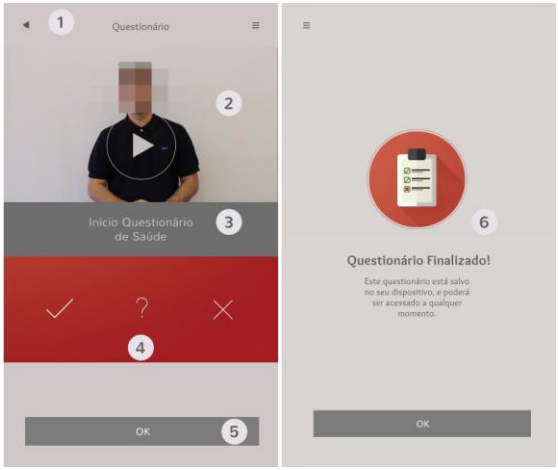
The dashboard in Figure 10 provides access to two main areas: Health Care Questionnaire and Dental Procedures Translation. Following the numbers in the image, there are: 1) User menu, for secondary options such as a help and logout, 2) Health condition questionnaire access, 3) Access to Dental Procedures Menu.

Figure 10: Dashboard

Source: Author

Health condition questionnaire in Figure 11. Following the numbers in the image, there are: 1) Back Button (Return), 2) Question translated in sign language (auto play), 3) Question subtitle, 4) Action buttons (yes, no and I don't know), 5) Confirmation Button, 6) End of questions screen with print/save options.~

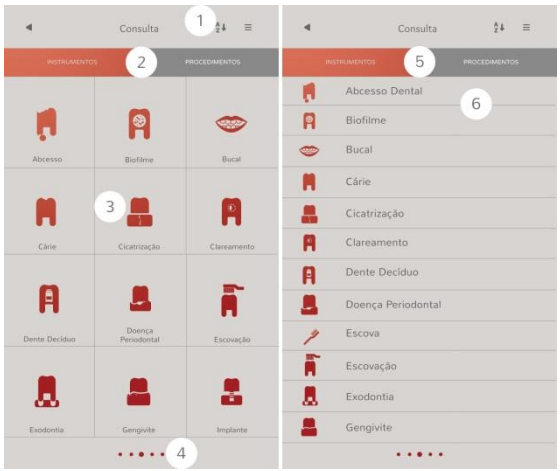
Figure 11: Health Related Question



Source: Author

Translated Procedures Menu, Figure 12. Following the numbers in the image, there are: 1) Change to line menu (alphabetic), 2) Filter between Procedures and Tools, 3) Access translation, 4) Page slider, 5) Filter for Procedures and Tools, 6) Alphabetic menu.

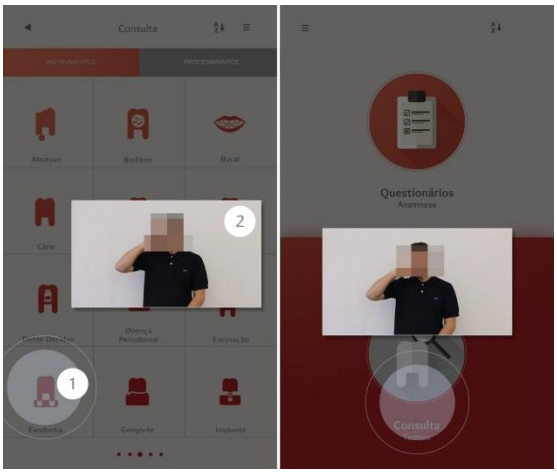
Figure 12: Translate Procedures Menu



Source: Author

Real time translation to help users navigate the app, Figure 13. Following the numbers in the image, there are: 1) Tap and hold for real time translation, 2) Temporary translation window.

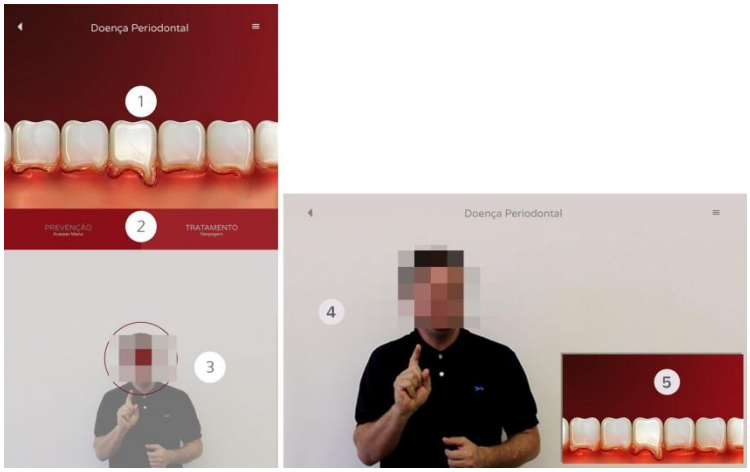
Figure 13: Real Time Translation



Source: Author

Translation screens, Figure 14. Following the numbers in the image, there are: 1) Procedure illustration, 2) Related words shortcuts, 3) Translation in Sign Language, 4) Land- scape mode, 5) Press the box to alternate between video and illustration.

Figure 14: Translation Area



Source: Author

4.9 Tests with Hearing Impaired People

The final usability test was performed with nine deaf people and five dentists. Each pair (deaf and dentist) simulated a dental care assistance citation with the app's assistance. At the end, the participants answered a questionnaire with 24 questions about usability and HCI. As a result, some corrections have been suggested, they are: 1) Add the translation for the term pain, 2) Change subtitles position, because it causes interference, 3) Create a PC version of the app, 4) Review related word shortcuts, 5) Re-size some icons, 6) Re- place YES and NO buttons, with positive and negative hand gestures icons.

From the test it was possible to calculate success points for the prototype. The grade obtained by counting the questions contained in the questionnaire, in a grade system from 1 to 5, the grade obtained was 4,329 and correspond 86.5% success. The overall satisfaction with the app was 4.64 and corresponds to a 92.8% success rate. Thus the app has reached the proposed goal, and it has great potential to help hearing impaired people.

After this phase, another usability heuristic evaluation was performed with Usability professionals, as a complement of the user tests: The app seeks to understand as much as possible the reality of the public involved, applying the required tools the software employs sign language in all its processes.

Good navigation map created in order to simplify the user's journey. It is based on standards aligned with the current scenario of digital applications.

5. CONCLUSIONS

To finish this research, first we will return to the question that started it: How to set up a model of software-assisted interaction that efficiently simplifies the communication be- tween the Dentist and the hearing impaired patient?

To understand the dimension in order to respond to the problem, this research proposed an approach based in a validated development process that proves itself

extremely efficient, principally in that context, where none of the members have previously knowledge about the problem and the user's problems. During the entire process, it was possible to verify the need for assistive tools to aid the hearing impaired people and at the same time promote sign language as independent and structured language.

In this context, where sign languages are treated as a bridge to access the written language, it was emphasized the need for a tool that transmits to listeners, the importance of accessibility within clinical context.

Finally the application for dental care emerges, allowing efficient communication between patient and dentist, as well as fostering the interest in both parties by the universe of each other. In this context the illustrations entered as a link between two different languages, avoiding ambiguities.

The multidisciplinary team in the project was vital to make sure the union of written, gestural and visual language was well developed. For the next projects, the team decided to keep the method adopted here, for it was effective in meeting the needs of a specific user. However, continuous improvements will occur as new assistive needs emerge.

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