SHORT PAPER

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Development of an app for the dental care of Deaf people: Odontoseñas

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Abstract

Background Most Deaf people are often illiterate and communicate via sign language, hindering their dental care, causing high levels of oral morbidity and feelings of unfairness by the dental staff.

Objective To achieve effective communication between the dentist and the Deaf patient using an app.

Materials and methods Focus group were conducted by a team comprising dentists, Chilean Sign Language (ChSL) interpreters, Deaf people and a software programmer to identify the most prevalent and important phrases used during dental care. A Minimum Viable Product App including draft videos in SL were developed and evaluated by external teams through in-office simulations and surveys. Evaluation by Deaf people and dentists was carried out using the Dental Visit Satisfaction Scale and System Usability Scale, respectively. Improvements were made in each cycle, until reaching agreement for a final (release) version.

Results Thirteen ChSL videos were recorded and incorporated in the App Odontoseñas. The overall usability of the software scored 96 points over 100. The overall satisfaction of Deaf people without the software was 21, and with the software was 29 over 30.

Conclusions Odontoseñas gives relevant information about dental care, facilitating diagnosis, treatment and improving oral health care experience for the Deaf patient.

Keywords Dental care · Hearing loss · Dental care for the disabled · Mobile applications

1 Introduction

Hearing impairment ranks third amongst all disabilities [1]. Medically, deafness is defined as an alteration in a reduction or loss in the ability of perception or processing of sounds, and classified according to etiology, degree of hearing loss, location of the lesion and time of onset [1, 2]. A considerable percentage of hearing-impaired people call themselves "Deaf", with a capital D, defining themselves as members of a Deaf community with its own language, culture, customs and values. Most Deaf people are illiterate and communicate via sign language (SL), which is a complex visual–spatial language that differs from spoken languages in syntactic, morphological, and phonological levels [2, 3]. SL differs between countries, it has been recognized in the Convention on the Rights of Persons with Disabilities (CRPD) and in more than 30 countries [4, 5].

Deaf patients experience major communication barriers in health care settings, impacting the quality of health care they receive. This is a worrying issue since poor health care communication can adversely affect health outcomes [6, 7]. Specifically, in dental care, dental staff lack the adequate training to meet the needs of the Deaf, mainly due to communication issues making it difficult for them to access dental care [2]. Given the above, Deaf people show high levels of oral morbidity and report feelings of discrimination by the dental staff. Also, this situation forces them to use their parents as interpreters, restricting their independence and right to privacy [2, 8, 10]. This situation is aggravated by the

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lack of knowledge of Deaf people about dental procedures [9, 10].

On the other hand, there is an exponential growth of smartphone users and a large market of mobile Apps for many purposes, including health and oral health care [11]. Unfortunately, most of the mobile apps intended to achieve an effective communication rely on the misconception that most Deaf people are literate [12]. Moreover, the small percentage of the literate Deaf people have a low health literacy and ignore specific terminology that health professionals use [13]. Thus, our aim is to achieve effective communication between the dentist and the Deaf patient through the development of a software for mobile devices.

2 Materials and methods

An iterative process was conducted based on lean methodology (Fig. 1) [14], resulting in three stages.

2.1 Stage 1

2.1.1 Video generation

In the first stage, the developer team comprising three dentists (two with an M.Sc. and one with a Ph.D.), four Deaf people (with a technical degree in special education), a software programmer (with an M.Sc.) and two Chilean SL (ChSL) interpreters (one with a psychology degree, and a teacher with a special education degree) participated in three consecutive focus groups.

In the first focus group, relevant topics of communication barriers during dental care in primary public health care

Fig. 1 Iterative development process of the app

facilities (PPHCF) were discussed. The most prevalent topics concerned toothache, home care instructions after tooth extraction, endodontics and what will take place at the dental visit. Each member of the dental team had the task to ask dentists who work in PPHCF about the most prevalent and important phrases used during dental care according to his/her own experience and knowledge, and each member from the Deaf community had the task to ask Deaf people from different associations/foundations who attend PPHCF about the most prevalent and important concerns during dental care according to her/his own experience. In the second focus group, all the data collected regarding the most prevalent and important concerns of Deaf people, and phrases used during dental care by dentists were discussed and evaluated by the developer team. A total of 20 phrases were initially collected (Fig. 2a).

In the last focus group, the developer team selected the most prevalent and important phrases that would allow a convenient dental diagnosis and treatment. Different previous phrases were combined and rearranged (Fig. 2b). A maximum of 12 videos were considered suitable, as more videos would compromise the usability of the app and thus the interaction between the dentist and the Deaf patient, delaying the dental visit. Also, each video regarding questions to the Deaf patient was presented as multiple choice questions, so the Deaf patient would not answer in ChSL, which the dentist would not understand.

After selection of the 12 phrases most prevalent and important during dental care, they were recorded in draft ChSL videos; at random, 6 videos were recorded with a black background, and the remaining 6 with a white background. Also by random allocation, subtitles were placed in different colors: white, black and yellow. All videos were evaluated by a first group comprising three external dentists working in PPHCF who evaluated the videos in terms of dental terminology and phrases selected, and four Deaf people from the Deaf Association of Concepción with complete secondary education who, with the aid of an interpreter, evaluated understanding of the videos, including the colors, contrast, font and signs used and speed. After receiving feedback, a new focus group conducted by the developer team took place, and new ChSL draft videos were recorded (Fig. 3a, b).

2.1.2 App development

Concurrently, the programmer developed a first draft of an app for Android and iPhone mobile devices using a Corona (Coronalabs, CA, USA) framework, which was evaluated by the team in terms of colors, contrast, usability, performance and vignettes (Fig. 4a). The general structure of the framework was unanimously chosen. The vignettes proposed by the team were: all (*Todos* in Spanish), where
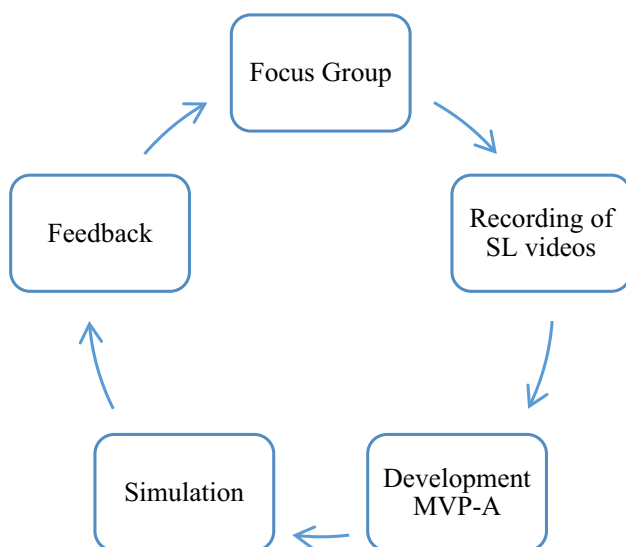
a. List 1

Dentist-proposed phrases	1. Do you have a toothache after drinking cold water?
	2. Do you have a toothache after drinking hot water?
	3. Do you have a toothache while eating?
	4. Do you have a toothache during your sleep?
	5. Does your tooth hurt the most at night?
	6. Does it hurt now?
	7. Does it hurt a lot?
	8. Does it hurt a little?
	9. Are you here because of a dental emergency?
	10. Are you here for a checkup?
	11. Are you here for a prophylaxis?
	12. You need a filling.
	13. You need a root canal treatment, but in Primary Care I can only provide a trepanation.
Deaf people's concerns	1. What will this dental visit be about?
	2. Do I need an X-ray?
	3. What is a root canal treatment?
	4. How do I take care after a tooth extraction?
	5. Can you repair my tooth?
	6. What are you going to do?
	7. Are you going to anesthetize my tooth?

b. List 2

Category	Title	Description
Identification	Identification	I am a dentist. Take a seat, I am going to examine you.
	Reason for dental visit	What is the reason for your consultation? Are you here for a prophylaxis? For a checkup? Or a dental emergency? Which one?
Diagnostic	Clinical examination	I am going to examine you. Raise your hand if it hurts.
	Duration of pain	When did the toothache begin? About a month ago? A week? A few days? Which one?
	Characteristics of pain	When does your tooth hurt? Does it hurt with cold beverages? With hot beverages? While chewing? Does it hurt more at night? Which one?
	Radiography request	I need you to have radiography. With this document you can book an appointment in SOME.
	What is a filling?	Your tooth is decayed. The caries must be removed with rotatory instruments, then it will be filled with a restorative material.
	What is a root canal treatment?	The tooth nerve is infected by caries. The nerve must be removed and then the tooth must be disinfected with specific liquids and instruments. Then it will be filled with a specific restorative material.
Treatment & instructions:	Filling	You need a filling.
	Need for exodontia or root canal treatment	The tooth nerve is infected. There are 2 alternatives to treatment: 1. Exodontia: I remove your tooth and the pain resolves. 2. Root canal treatment, which features 3 steps: - Removal of the tooth nerve and resolution of the pain. - Then you have to take this consultation request to SOME so you can book an appointment with a specialty dentist. - Once you finish your treatment, you must come here for a permanent filling.
	Anesthetize	I am going to anesthetize your tooth with an injection.
	Tooth extraction after care	1. You must bite gently on a roll of gauze for 1 hour. 2. Do not spit. 3. No vigorous activities for 2 days. 4. Do not rinse. 5. Do not smoke. 6. Do not use aspirin.

Fig. 2 List of phrases and concerns during dental visits proposed by dentists and Deaf people
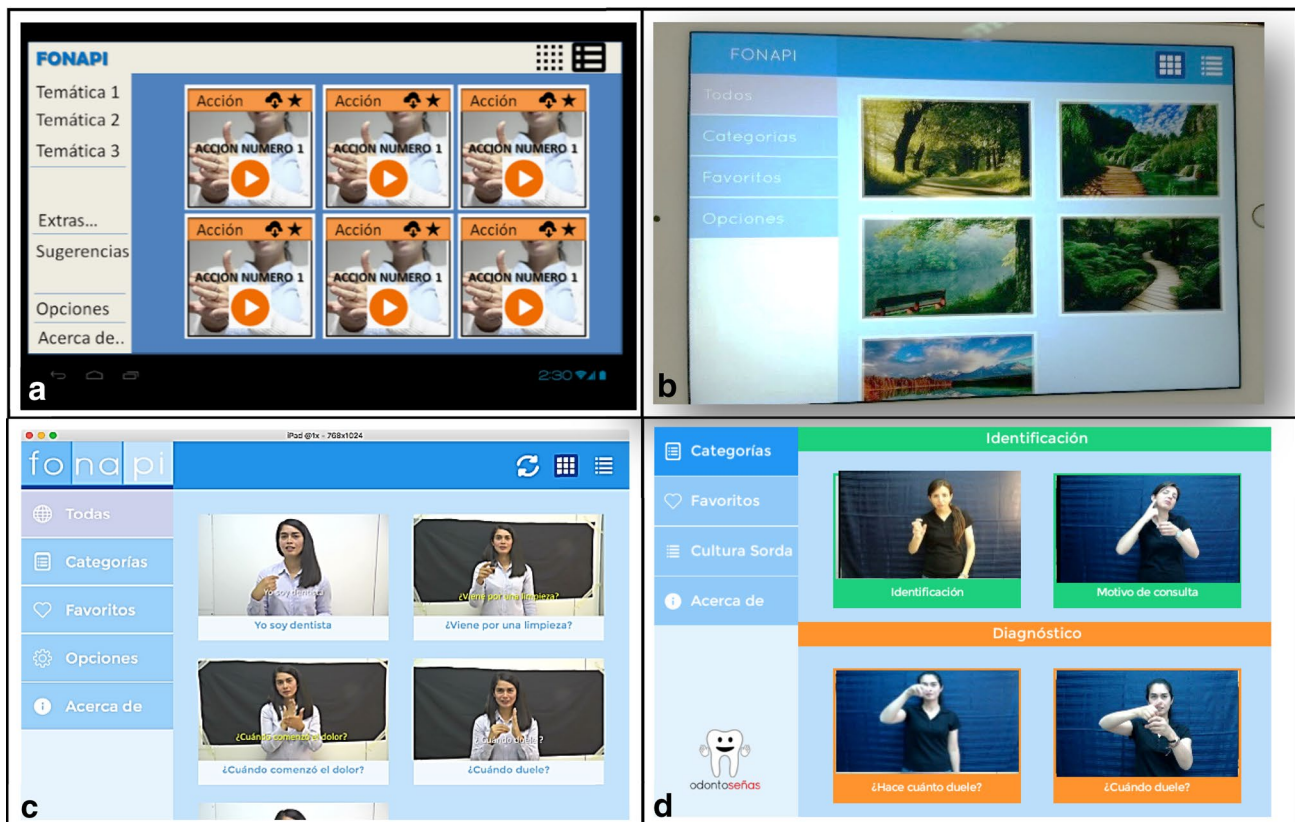
Fig. 3 Draft ChSL videos

Fig. 4 Wireframes and preliminary version of the app

you could access all videos; categories (*Categorías* in Spanish), where you could access the videos classified by category; favorites (*Favoritos* in Spanish), where you could access the videos marked as favorites; and options (*Opciones* in Spanish), where you could access the options. Regarding the color palette, different shades of blue were chosen. After receiving feedback, the programmer developed a new version of the app (Fig. 4b). This

version was evaluated by the team, and a new vignette was proposed, About (*Acerca de* in Spanish), where all information regarding the development team and funding can be found. Also, an icon was proposed to accompany each vignette for easier location. After receiving feedback, a new version of the app was developed in which the ChSL draft videos were incorporated, achieving a minimum viable product app (MVP-A) (Fig. 4c).

2.1.3 Simulations

All participants were informed about the study, and voluntarily accepted to participate and signed an informed consent. Deaf participants' informed consent was obtained using ChSL. All patients received a financial incentive, to pay their transport or other related expenses. Besides, after the simulation, the ChSL interpreter, jointly with the dentist, explained to the Deaf patient their dental diagnosis.

Three dental visits (simulations) involving a group of three external dentists who work in PPHCF and three Deaf people who attend PPHCF (from two Deaf organizations, with secondary education) were executed. In the simulations, dentists had to carry out a dental examination and explain to the Deaf patient his/her dental diagnosis with the use of the MVP-A. Evaluation by Deaf people was assessed by qualitative perceptions, through open-ended questions and suggestions in ChSL (Fig. 5a). Evaluation by dentists used the System Usability Scale (SUS) [15]. SUS includes ten items scored on 5-point scales numbered from 1 (strongly disagree) to 5 (strongly agree). To get the overall usability score, the sum of the item score contributions is multiplied by 2.5. Scores range from 0 to 100 in 2.5-point increments [15]. Also, any open-ended questions regarding any comments or suggestions in written form were recorded (Fig. 5a).

2.2 Stage 2

2.2.1 Video generation

After receiving feedback from the simulations (Fig. 5a), another focus group composed of the developer team was conducted. Evaluation of the feedback and improvements were discussed. A new video was incorporated which included common phrases such as "Hi, how are you?", "Yes", "No" and "See you; we are finished". Some signs were modified, and draft images, made by a graphic designer, regarding "root canal treatment" and "filling" were selected for better understanding. Also, a blue background and the use of a black t-shirt were proposed. After reaching agreement, new ChSL draft videos were recorded with the draft images incorporated. Randomly, subtitles were placed in white or yellow. All videos were evaluated by a second group. The second group was also composed of three external dentists working in PPHCF who evaluated the videos in terms of dental terminology and phrases selected, and four Deaf people from the Deaf Association of Concepción with complete secondary education who, with the aid of an interpreter, evaluated understanding of the videos, including the colors, contrast, font and signs used and speed. After receiving feedback, a new focus

COMMENTS & SUGGESTIONS

A. SIMULATION 1	Deaf people	Black background is better.
		Interpreters should use a black shirt for better contrast with the hands.
		Root canal and restorative treatment was not understood; suggestion of animated video.
		Relocate the camera focus, as the hands of the interpreter sometimes are not focused, and some signs are missed.
		Signs on dental emergency should be more specific; add mouth and pain signs.
		Very interesting app; just need to improve some signs.
	Dentists	The sequence of the videos does not have a logical order.
		It is difficult to locate the videos; there is a need for a classification.
		There is a need for an exact description of every ChSL video.
B. SIMULATION 2	Deaf people	Yellow subtitles work better.
		Blue background and black t-shirt has an excellent contrast.
		Speed of videos is adequate.
		Root canal and restorative treatment are now understood.
		Signs for the dental anesthetic video are not adequate; it is confusing.
	Dentists	Propose a video on how to salute the Deaf patient or tell him/her we are finished.
		Propose a video on exodontia.
		Propose a video on dental hygiene.
		Easy to use; videos have a classification; still need a logical order.

Fig. 5 Comments and suggestions from simulations 1 and 2

group conducted by the developer team took place, and new ChSL draft videos were recorded (Fig. 3c).

2.2.2 App development

Concurrently, after receiving feedback from the simulations (Fig. 5a), the developer team conducted a focus group. An organization of the videos with a colored layout was proposed. The vignettes "All" and "Options" were eliminated, as they were not needed, and the vignette Deaf Culture (*Cultura Sorda* in Spanish) was proposed. Also, an exact description of each ChSL video was requested. The programmer developed a new version of the app based on the requirements from the feedback of the simulations and the focus group. After achieving agreement, a second draft version of the app was developed, and the second draft ChSL videos were incorporated (Fig. 4d).

2.2.3 Simulations

Then, a second round of three simulations was executed. Again, the same group of dentists had to carry out a dental examination and explain to the same group of Deaf patients his/her dental diagnosis with the use of the second MVP-A. Evaluation by Deaf people was assessed by qualitative perceptions, through open-ended questions and suggestions in ChSL (Fig. 5b). Evaluation by dentists was done using an SUS. Also, open-ended questions and suggestions from the dentists in written form were recorded.

2.3 Stage 3

2.3.1 Video generation

After receiving feedback, a final focus group was conducted. Evaluation of the feedback and improvements were discussed. As draft images were approved for "root canal treatment" and "filling" videos, animations were requested from a graphic designer, according to the initial drafts. A blue background and the use of a black t-shirt were widely accepted by the Deaf community.

As all videos were accepted by dentists who work in PPHCF in terms of dental terminology and phrases selected, and all the Deaf participants understood the videos and approved the colors, contrast, font and signs used and speed, no further feedback was necessary. Final videos were recorded in a studio. Every video was performed by a Deaf person from the development team, with the aid of an interpreter and a dentist, also from the development team.

2.3.2 App development

Concurrently, the programmer developed a new version of the app based on the requirements from the feedback of the simulations and the focus groups. A new classification of the videos was proposed, and they were rearranged in a logical order. Information on the importance of SL and how to address a Deaf person was defined for the Deaf Culture vignette. Also, the incorporation of a new video with common phrases was requested. After achieving agreement, a final (release) version of the app was developed, and the final ChSL videos were incorporated.

2.3.3 Simulations

Finally, nine simulations were conducted in a dental office with a second group of nine external dental students or dentists that work in PPHCF and nine Deaf people with different degrees of hearing loss and/or use of hearing aids (Fig. 6). Dentists had to carry out a dental examination and explain to the Deaf patient his/her dental diagnosis without the use of the app, and then repeat the simulation with the use of the app. Evaluation by Deaf people was assessed using a modified version of the Dental Visit Satisfaction Scale (DVSS) [16]. Originally, the DVSS included ten items scored on a Likert scale from 1 to 5 (strongly disagree, disagree, uncertain, agree and strongly agree). An overall satisfaction score is obtained by summing the scores of all ten items, with total scores ranging from 10 to 50 [16]. In our modified version, we maintained the six items related to "Information-communication" and "Understanding-acceptance" and eliminated the four items regarding "Technical competence" as no dental procedures were executed during the simulations, reducing the maximum score to 30 points. Evaluation by dentists was done using SUS. Also, any open-ended questions regarding any comments or suggestions in written form and in SL were recorded.

Deaf participants Hearing Loss degree and use of hearing aids

1.	Profound hearing loss, no hearing aid
2.	Profound hearing loss, no hearing aid
3.	Profound hearing loss, no hearing aid
4.	Profound hearing loss, no hearing aid
5.	Profound hearing loss, no hearing aid
6.	Moderate hearing loss, hearing aid
7.	Moderate hearing loss, cochlear implant
8.	Moderate hearing loss, cochlear implant
9.	Low hearing loss, hearing aid

Fig. 6 Deaf participant's characteristics

3 Results

A total of 13 videos in ChSL were recorded. Each video has a Deaf person wearing a black shirt, yellow subtitles and a royal blue background (Fig. 7).

An app compatible with iPhone and Android for mobile and tablet devices was developed. The app layout consisting of a left menu with the vignettes of videos, favorites, Deaf Culture and about. In the video category, the videos are distributed in three categories and arranged in a logical order, i.e., identification, diagnosis and treatment/medical indications. Each video can be selected and de-selected as a favorite video, which will appear in the favorites display. Also, each video has a full text description of the exact dental phrase of the ChSL video. The Deaf Culture item displays information on the Deaf community and contact details of a specific Deaf Cultural Centre. Finally, all participants of the project are named in the about and funding items (Fig. 7).

For the first six simulations (Stage 1 and 2), the median SUS score on the app usability was 88 (range 83–93). For the final Simulations (Stage 3), the median SUS score on the app usability was 96 (range 85–100).
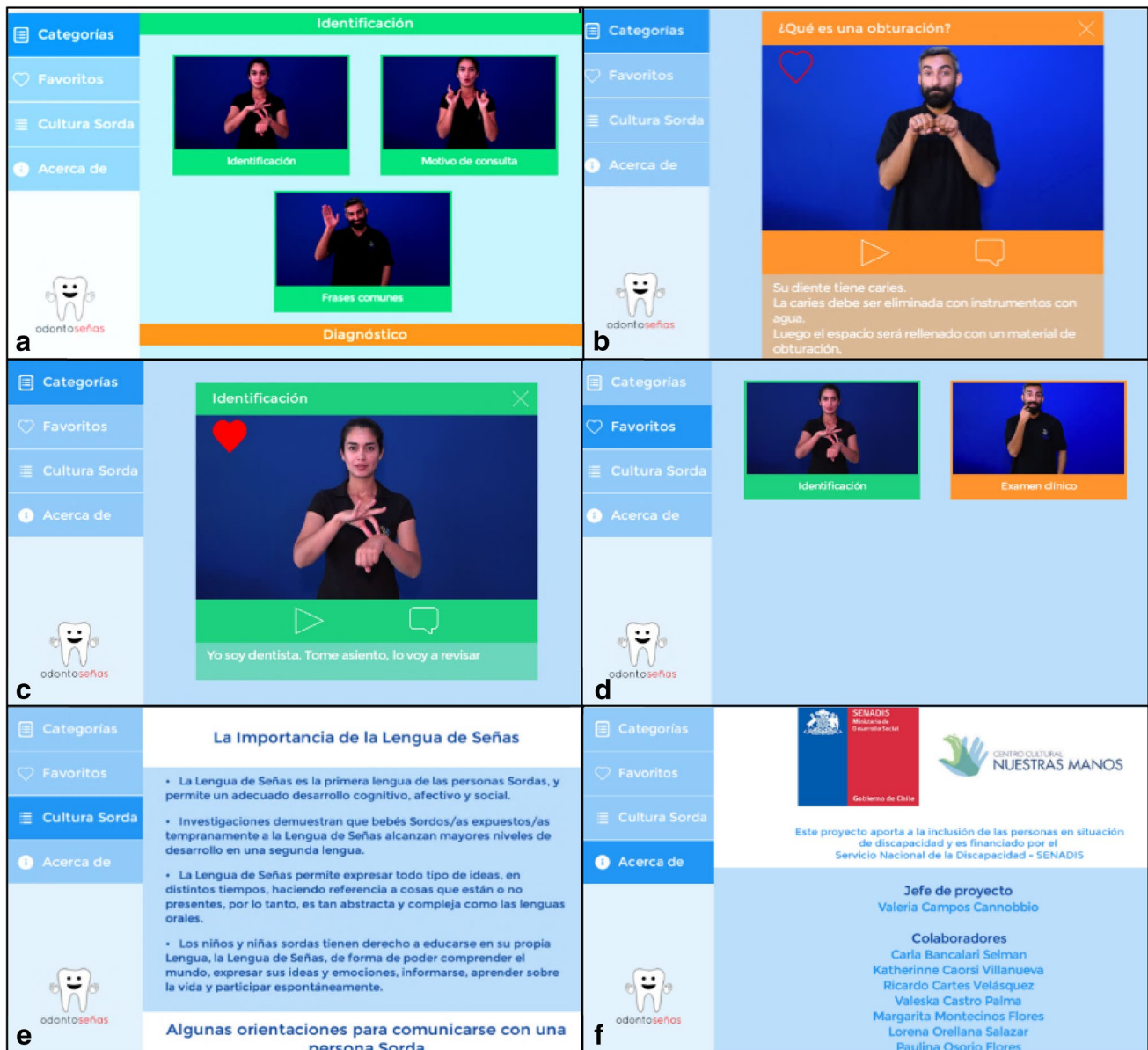

Fig. 7 General display of the app with the left menu. **a** Video display; **b** selection of a video. Full description below the video; **c** selection of a favorite video; **d** display of favorites videos; **e** Deaf culture information; **f** participants of the project and funding

All (100%) of Deaf people were satisfied with their dental examination using the app (Fig. 8). The median DVSS score without using the app was 21.3 (range 10–30). The median DVSS score with the use of the app was 29.3 (range 24–30). The median DVSS score for Deaf people with profound hearing loss without using the app was 14.8 (range 10–18). The median DVSS score with the use of the app was 28.8 (range 25–30). The median DVSS score for Deaf people with low to moderate hearing loss was 29.5 (range 29–30). The median DVSS score with the use of the app was 30 (range 30).

4 Discussion

In this R&D project, a relevant need of the Chilean Deaf population was met with the joint work of dentists, Deaf people, ChSL interpreters and the financial support of the National Disability Service (*Servicio Nacional de la Discapacidad*, SENADIS).

Every Deaf person was satisfied with and grateful for the app. Its high acceptance could be due to the incorporation of Deaf people in the developer team, the final recipients and keeping with the CRPD statement "*nothing for us, without us*", recognizing that Deaf people are capable of making decisions and of being active members of our society [5].

Even though Odontoseñas has been well received by the Google Play community, it has limitations. First, it does not allow fluent communication as it does not replace a ChSL interpreter. Also, this app is not very helpful for private practice, as it has few videos, and those are focused on the dental visits in a PHCF. However, as a positive aspect, this small quantity of videos makes the app easy to use, and is sufficient to provide independence/privacy to the Deaf patient during his/her dental visit. This is relevant as dentists in PHCF in Chile only have 20 min per patient.

We also included dental students in the *Simulations*, as every dental student in Chile has a 5-month internship in PHPC before obtaining their dental degree, so it is highly probable they encounter a Deaf patient during that period.

It is important to notice that with Odontoseñas, Deaf patients were able to understand their diagnosis and the treatment they needed, in contrast to what has been reported earlier by Samnieng [10] and Holt [9], where 38.1% and 68.13% of the patients, respectively, did not understand what will take place at the dental visit.

Odontoseñas can be used during dental care for different scenarios: a Deaf person with his/her hearing parent, a Deaf person with his/her Deaf parent, or a hearing child with a Deaf parent.

Odontoseñas is a free downloadable app available at iTunes and Google Play for an indefinite period and is registered under creative commons. It is significant to mention that this app is one of a kind worldwide and it already has more than 2800 downloads and a 5/5 score.

As the Deaf community experiences communicational barriers during dental care worldwide, and SL varies between countries [2, 4], it is therefore necessary, and mandatory, that different countries that ratified the CRPD [5] around the world should update this app with their own SL to comply with the convention.

Although the developing team strongly believes that future steps aim at health professionals learning ChSL, they acknowledge that it is a long way off. In a parallel effort, future steps should focus on developing tools similar to Odontoseñas for different health scenarios with nurses, pharmacists, physical therapists, physicians and especially for health emergencies.

Another issue to address is the small sample used in this preliminary study, as the focus of this paper is to describe the development process. However, it must be considered that the final sample size of Deaf people comprised 12 external Deaf participants, 4 Deaf people in the development team, plus at least 20 other Deaf people who evaluated the videos. In summary, over 30 Deaf people evaluated the app during its development and release process.

As part of future research, we plan to incorporate new ChSL videos regarding the Chilean Public Health Policy named GES (*Garantías Explícitas en Salud*, Explicit Health Guarantees), to broaden access to health information for the Deaf community.
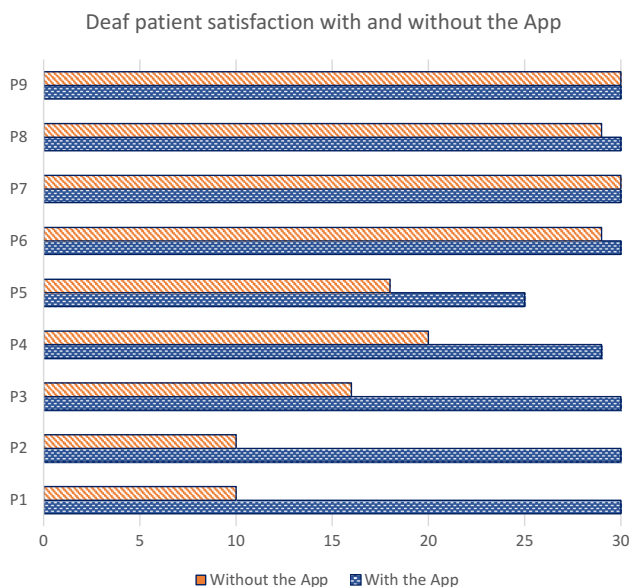

Fig. 8 Deaf patient satisfaction with and without the app, final simulation

5 Conclusion

Odontoseñas gives relevant information about dental care, facilitating diagnosis and treatment and improving the oral health care experience for the Deaf patient. It decreases the communication barrier between the dentist and the Deaf patient.

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