SignSupport: A Limited Communication Domain Mobile Aid for a Deaf patient at the Pharmacy

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Abstract- This paper discusses a prototype for a communication aid on a mobile phone to support a Deaf[1] person visiting a public hospital pharmacy. The aim is to prevent problems of non-compliance to treatment due to poor communication between a Deaf patient and a pharmacist. We studied the communication exchange between pharmacists and Deaf patients in a pharmacy setting in order to extract the most relevant content exchange between the two parties. A prototype was developed on a mobile phone and iteratively tested using role plays, questionnaires and focus groups with pharmacy students and Deaf participants. The prototype allows pharmacists to input text and make selections that provide detailed medical instructions in signed language to a Deaf patient. The prototype demonstrates the feasibility of encoding a limited communication flow on a mobile device, with carefully sequenced sign language videos that a Deaf patient can watch and understand in order to take medicine correctly.

Index Terms— Internet services & end user applications; Mobile apps; Software design.

I. INTRODUCTION

This paper describes a mobile prototype named SignSupport that operates in a limited communication domain to assist a pharmacist at a public hospital pharmacy to dispense medication to a Deaf patient. The need for concise and clear communication between the pharmacist and a Deaf patient is extremely important for the process of medicine dispensing and patient recovery. This research project concerns the definition and encoding of the communication flow between the pharmacist and the Deaf patient and involves the design, development and deployment of a working prototype with the main goal of providing pharmaceutical information to a Deaf patient in South African Sign Language (SASL) on a mobile device.

Deaf people in South Africa often have problems communicating with hearing people because they use SASL, not spoken language. It is a frequent misunderstanding that a signed language is a signed form of a written/spoken language. This is not true, and many South African Deaf people have low written/spoken language literacy; thus reading, writing and lip-reading are not viable options for them [1]. Registered sign language interpreters are both expensive and very scarce in South Africa. Deaf people in South Africa use SASL as a mother tongue and prefer to use it whenever possible. Deaf people use services like Short Messaging Service (SMS), WhatsApp, Mxit, email, chat (such as Google talk and Skype) and fax to communicate with each other and with hearing people [2]. However, poor text literacy hinders communication, and in a medical context, only signed language can precisely convey information in a way that Deaf people can clearly understand [3][4].

SignSupport is a communication aid on a mobile phone that shows SASL videos to Deaf end users. The current focus is to convey instructions on how to take medication and is based on prior work by Looijesteijn [3], an industrial design engineering student from Delft University of Technology (TU Delft). He designed the first SignSupport version, a mock-up of a mobile phone on a PC that allowed a Deaf person and a doctor to communicate with each other using pre-recorded SASL videos. The mock-up asked a Deaf person questions in SASL. After the Deaf person answered the questions, the answers were presented to a hearing doctor in plain English. The doctor read the summary of symptoms and responded using an English lookup dictionary. The Deaf person then watched a corresponding SASL video of the response [3].

Mutemwa implemented that mock-up on a Symbian phone and employed a guided set of web pages with a combination of SASL videos and English text [4]. This enabled a Deaf patient to tell the doctor the symptoms they are experiencing, how long they have been experiencing them etc. However, it was soon realized that it was impossible to pre-record all possible communication topics between a patient and a doctor.

Chininthorn, also from TU Delft, with input from a local Deaf community, re-oriented SignSupport toward pharmacy [5]. The main reason was that the pharmacist/patient exchange is more limited and we could pre-record and store a restricted communication flow on a mobile phone. Chininthorn's work concentrated on conversations between a pharmacist and a Deaf patient [5]. From her design, we crafted a solution that can be implemented on a mobile phone: the pharmacist uses a typical touchscreen-based user interface to enter information about a prescribed medication, and the Deaf user can view that information in SASL. All videos are pre-recorded and loaded on the phone. We do not utilize automatic natural speech or sign language recognition because these technologies cannot currently guarantee

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[1] Deaf with a capital 'D' is different from deaf or hard of hearing in that Deaf people primarily use sign language to communicate and this defines their sense of culture; similar to other groups that use spoken languages like Afrikaans, English or isiXhosa.

enough accuracy for medical instructions. For example, with an automated sign language system, it was found that on average only 61% of an avatar's phrases can be identified correctly [6]. Moreover, using an avatar in real time requires powerful computers that are very expensive [7][8].

The rest of this paper is organized as follows. Section II covers work related to sign language communication aids and mobile video for sign language. Section III explains the methodology used to realize the current SignSupport prototype. Section IV discusses and explains a complete scenario illustrating how SignSupport is used. Section V describes the design and implementation of SignSupport in detail. Section VI presents and analyzes data collected from role-plays and a trial with Deaf participants and final year Pharmacy students. Section VII concludes and outlines future work.

II. RELATED WORK

Deaf people prefer to use signed language to communicate, and many Deaf people are text illiterate. Thus, when a Deaf person wants to communicate with a hearing person, communication can be difficult and frustrating. For this reason there have been attempts to design technologies that can work as automatic interpreters between a Deaf person and a hearing person [2][7]. Such attempts have now moved onto the mobile platform because mobile phones provide ubiquitous services with text and video. However not many systems are developed for medical use for Deaf patients, and more specifically, for those Deaf people that do not possess text literacy.

In the UK, an experimental system called TESSA was developed to aid with transactions between a deaf person and a clerk in a post office by translating the clerk's speech to sign language [7]. Developed in collaboration with the UK Post Office, TESSA combines speech recognition technology and state of the art virtual human animation to enable post office workers to communicate with Deaf customers. A post office clerk speaks into a microphone, which is then recognized by a computer speech recognition system. The speech is converted to British Sign Language and signed by a virtual human to the Deaf customer. TESSA was developed for the post office scenario because most of the conversations are predictable and simple to follow. The movements of the virtual human are copies of those of a native sign language user. Software specially developed for the project captures the signer's hand, mouth and body movements using a variety of electronic sensors. These movements are then stored and used to animate the avatar when required [7].

TESSA is a part of the larger ViSiCAST project that seeks to improve the quality of life for Deaf people by widening their access to services and facilities enjoyed by the community at large [8]. A major application area for ViSiCAST is to bring virtual human signing into the Internet environment. The project identified a number of aspects of life where the integration of Deaf individuals in society would be improved if sign language communication were available: such as access to public services, commercial transactions and entertainment [7][8]. The ViSiCAST team started their first prototype with real sign language videos and later changed to using an avatar. The objective of the ViSiCAST project was to produce adaptable communication tools allowing sign language communication where only speech and text are available at present. A face-to-face transaction virtual signing system was tested with TESSA. ViSiCAST intends to go beyond TESSA and also translate sign language to text or speech.

MobileASL is a video compression project in the USA that seeks to enable low-cost low-bandwidth sign language communication with mobile phone technology [9]. MobileASL works on commercial phones that are accessible to Deaf people. The motivation of MobileASL is to make as clear a sign language video as possible to transmit over the network [9]. Cavendar *et al.* conducted user studies with members of the Deaf community to determine the intelligibility effects of video compression techniques that exploit the visual nature of sign language. Unfortunately, the Deaf community in the USA cannot yet take advantage of this new technology. Preliminary studies strongly suggest that even today's best video encoders cannot produce the quality video needed for intelligible American Sign Language in real time, given the bandwidth and computational constraints of even the best mobile phones. MobileASL concentrates on three major areas when manipulating video for sign language use; *Bitrate*, *Frame rate* and *Region of interest*. They deemed these three variables important for using sign language videos on cellphones.

The current version of SignSupport is similar to TESSA in that it also focuses on a limited communication domain; yet unlike TESSA, SignSupport does not employ automated translation of or to signed language. SignSupport, however, does pay attention to the quality of stored sign language videos on the phone, similar to the MobileASL project that also found that the minimal frame rate and resolution is between 10 and 15fps (frames per second) for transmitting sign language video over a network [9].

III. METHODS

This section gives a detailed explanation of the research strategies used in this study. This study is based on several years of research and collaboration by a multi-disciplinary team of professionals [3][4][5]. Section A introduces team members, and their roles and contributions. Section B explains community-based co-design, a design method that explores different solutions in a complex design space with the target community. Section C details the steps taken to collect requirements and design the system.

A. Multi-disciplinary approach

Members of our multi-disciplinary team have a wide range of expertise and it is a challenge to direct and channel their skills. Here is a brief explanation of each member's role.

Deaf participants are in many ways the leaders of the project; they decide what the project is and how they would like to use it, and most of the user requirements come from them. How SignSupport features are presented, such as video quality, simple login, icon meaning, and reminders, are completely dependent on the Deaf end users.

Pharmacists are responsible for making sure that the prototype is consistent with their professional code of practice. They ensure that patient data is adequately acquired; that the prototype follows a known logic when dispensing and they also identify what medicines and illnesses to include in trials.

*Industrial design engineer*s involved both Deaf and pharmacy participants and acquired user requirements by means of role plays, questionnaires and focus groups (see Figure 1) They presented this information in the form of a design/sketch on paper that best represented the expectations of both Deaf and pharmacy users. The industrial design engineers designed SignSupport's interfaces (see Figure 2) based on interactions with end users over several versions starting from Looijesteijn's mock-up [3], to Mutemwa's medical diagnosis [4] then finally to Chininthorn's pharmacy design [5].

A *Deaf education specialist* was a link between the technical team members and the Deaf community members. She analyzed the sentences extracted from the role plays between patient and pharmacist, structured the sentences to make sense in SASL and was always present during SASL video recordings and training sessions.

The *Computer scientist*s' core duty was to bring the software application to reality, to evolve the human computer interface and optimize it to seamlessly fit into everyday use for both types of end users. We also showed a prototype to a mobile interaction designer at the University of Cape Town (UCT), who looked at how end users interfaced with SignSupport. He helped solve the problem of overloaded menus by suggesting hierarchical menus [10].

B. Community-based co-design

From the very beginning of the study it became clear that we needed to find an approach that would help this diverse team of experts work together in an effective and efficient way with the Deaf community and pharmacists. We call the methodology community-based co-design [11]. Naturally, traditional Human Centered Design (HCD) methods were chosen for the community-based co-design process, as these techniques facilitate the participation of the target groups to help design and develop a solution that they want, and that suits their needs and lifestyle. Community-based co-design required us, at every stage (see Figure 2) to refer back to the participants to show how their suggestions had been incorporated into SignSupport. During all interactions with Deaf participants, we had a professional sign language interpreter assisting with the communication process. Likewise, with all interaction with pharmacists, usually final year Pharmacy students at UWC, we had a senior pharmacist along with research assistants to facilitate activities.

C. Iterative design and development

The most important process for realizing SignSupport is to continually integrate end-user requirements and feedback into the design process. Figure 1 shows a timeline of a series of activities to achieve this goal.

Focus group sessions were conducted with members of the Deaf Community of Cape Town (DCCT), which is a Non-Government Organization (NGO) in Cape Town, which supports Deaf people deal with social issues. DCCT has over a thousand members who are Deaf. Members of our group have been testing Deaf telephony systems with members of DCCT for over ten years [2]. There are nine steps we followed to gather results as seen on Figure 1 described in detail below:

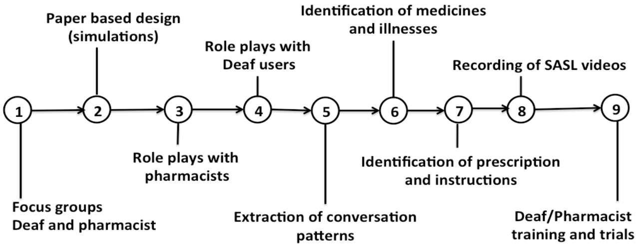

Figure 1 A timeline of events showing how requirements were gathered. Each event with end users also acted as a feedback session showing participants how their input was factored into the process.

Step 1 (focus groups) Pharmacists discussed the challenges of dispensing medication to a patient using spoken language with whom they could not communicate. We found out that most hospital pharmacies have a mechanical wheel that allows them to communicate, in text, with a patient who speaks a different language, but no such aid exists for Deaf patients. Deaf participants were asked to draw a solution that they thought would help them in the hospital setting.

Step 2 (paper prototype) Discussions in Step 1 led to the design of a paper prototype that was used as a base line to explore user expectations from both target end user types.

Steps 3 and 4 (role plays) All the participants were introduced to the paper prototype separately. Deaf people and pharmacists were asked to participate in a small simulation exercise. We observed the interactions between a student pharmacist and a simulated Deaf patient. Deaf users interacted with a surrogate pharmacist, were the pharmacist was dispensing medicine using a paper prototype. During these role plays we concentrated on the seven steps a pharmacist must take when dispensing medicine: *Greeting, Patient Identification, General History, Clinical Reasoning, Clinical Decision-making, Patient Questions and Closing*.

Step 5 (conversation mapping) After Steps 3 and 4 we studied video footage of the interaction between the two parties during the role plays. We also visited pharmacies to covertly observe pharmacists interacting with patients in a real environment. We looked at the mannerisms of the two users from the moment they start to interact with each other, e.g. we study what the pharmacist says to the patient, how they say it, and at what stage of the interaction they say it. We look at the steps users take to dispense/collect medicine. From Steps 3 and 4, we successfully recognized and uncovered most, if not all, of the conversations that occur often between pharmacists and Deaf patients at public hospitals. The communication flow at the pharmacy was limited in a similar fashion to TESSA which covered about 90% of the communication at the post office [7].

Step 6 (disease/medicine selection) We asked both types of participants to chose several illnesses to include in the prototype. During focus group sessions they identified the most common diseases that they deal with. SASL videos were recorded around this restricted list of illnesses to populate the prototype, e.g. when a pharmacist selects a disease (in text), a corresponding SASL video plays for a Deaf patient.

Step 7 (identification of prescription and instruction) SignSupport acts as a virtual prescription and thus it has to contain all of the elements of a paper prescription. We had a look at how doctors format the prescription script that is handed to the patient. The instructions on the prescription and the order in which those instructions occur were studied and incorporated into SignSupport so that when the pharmacist dispenses, s/he follows that natural flow.

Step 8 (SASL video recording): We recorded a limited number of videos to represent the possibilities determined in Steps 6 and 7 (see Figure 3 and Figure 4). A conversation script was created and used to guide recording SASL videos in SASL. An interpreter translated each message.

Step 9 (training and trial): Eight Deaf participants and then eight pharmacists were trained on how to use SignSupport. Pharmacists were given SignSupport on an Android phone at the UWC School of Pharmacy after they had been given a short presentation. They were encouraged to 'play' with the application and provide feedback. Deaf participants were trained at DCCT and also received a short presentation. They had hands-on usage with SignSupport, and gave suggestions. Both sessions lasted three hours and the sessions were video recorded. A trial then took place at the UWC School of Pharmacy dispensing unit including all trainees. Deaf and pharmacy participants were asked to interact using SignSupport at an actual pharmacy counter. Four video cameras recorded the interactions from various angles. After participants finished the trial, they were asked to answer a questionnaire individually and later participated in a focus group discussion.

IV. USING SIGNSUPPORT

This section describes how SignSupport is used in practice. The next section will delve into implementation details. SignSupport requires an Android phone running at least version 2.3.3. Once installed, SignSupport opens with a tap. Figure 2 shows two typical interface screens, one for the pharmacist and one for a Deaf user. We are working with a Deaf NGO, and any member of DCCT could feasibly borrow the phone when they go to the hospital and return it when they have completed their medical treatment.

A doctor diagnoses an illness and hands the Deaf patient a paper prescription as per normal. The Deaf patient takes the paper prescription and the smartphone with SignSupport to the pharmacy. While in a queue at a hospital pharmacy, the Deaf user enters background information including medicine allergies, gender, access to clean water, pregnant or not and other information that will help the pharmacist dispense appropriate medication. The background information complements the information about the patient on the patient card at the pharmacy.

The Deaf patient must unlock SignSupport by entering a four-digit PIN that protects the patient's medical information. The Deaf patient hands the phone to the pharmacist together with the paper prescription. The pharmacist is able to see the patient's background history and can check for problems like allergies and environmental conditions before dispensing the medicine. The pharmacist interacts with the application's interface in order to dispense the prescribed medication, as shown on the left side of Figure 2, by tapping information on the phone's display, selecting from the provided options and taking a picture of each medicine.

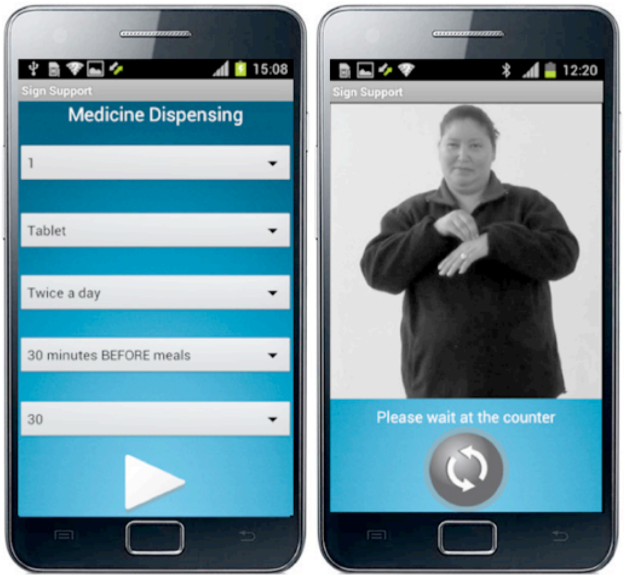

Figure 2 The pharmacist's dispensing screen is on the left, and a Deaf patient's SASL view is on the right.

Since every screen activity follows the established pharmacy code of practice [12], this process should be easy and natural to follow for a trained pharmacist Information about each prescription is delivered in a SASL video for the Deaf patient. SignSupport allows the Deaf patient to review instructions for any prescribed medication in SASL at any time. It also reminds the patient when to take their medicine and warns them if they are about to run out of medicine for chronic conditions like hypertension, diabetes or cancer, all in signed language. Note that the text phrase beneath the video is not meant for the Deaf user, and is a key phrase to help a non-signer follow the flow.

V. DESIGN AND IMPLEMENTATION

This section breaks down technical details of SignSupport. Figure 3 shows a high-level use case of the entire system and its role players.

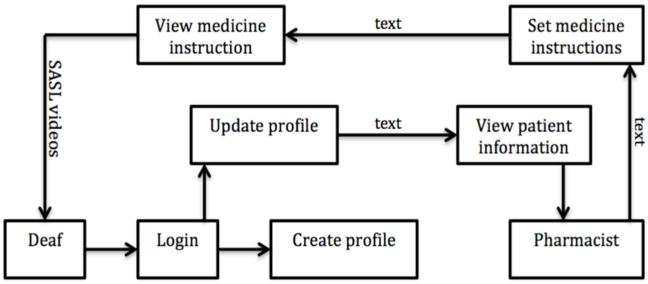

Figure 3 High-level use case of overall system: The Deaf patient provides text to the pharmacist via SASL video interaction and the pharmacist provides SASL video to the Deaf user via a graphical user interface with text.

A great deal of effort has been dedicated to providing acceptable video quality to sign language users. We have edited the video size to be 640x700 pixels in MPEG-4 format at 30fps. The MobileASL team found that at between 10fps and 15fps users could not distinguish the difference in video quality [9]. While this is true, the video quality can still be poor at such rates. A higher frame rate helps with legibility [6][9] during video compression from MOV to H.246. We have coded SignSupport to fit on most currently available Android phones. The phones we used had 2 gigabytes (GB) of external storage space or more, 1 GB of RAM and a back-facing camera. The SASL videos have an average length of about 2:00 minutes and they were all recorded at the same location with the same background and lighting conditions. We removed the sound from the videos to make them smaller and set all videos to grayscale as suggested by Looijesteijn [3]. This is because pixels have only one property, i.e. colour. The colour of a pixel is represented by a fixed number of bits. The more bits, the more subtle variations of colours can be reproduced and thus the larger the video. For this reason we chose to make the videos black and while. This allowed us to essentially give each pixel either a black or white colour resulting in a smaller video.

The user interface was coded with Extensible Markup Language (XML), a language that allows the definition of tags, while having the qualities of HTML [http://www.w3.org/XML/]. The pharmacy backend is coded in Java and has four layers as seen in Figure 4.

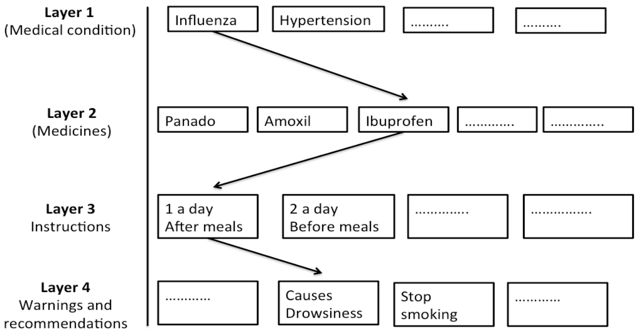

Figure 4 A layered view of the pharmacy backend that indicates how a prescription is encoded.

Layer 1 contains possible medical conditions (currently restricted in number to code and trial the prototype).

Layer 2 holds the medicines in the system (similarly restricted). Videos from Layers 1 and 2 appear on different screen activities at different times, so these parameters are labeled with the same name that the SASL videos are stored with. To fetch and play them, we just reference the name of the disease or medicine to the correct directory on the memory card.

Layer 3 holds combinations of prescription instructions with different permutations (see Figure 5). Videos in this layer are recorded as complete sentences in SASL. There are three parameters as seen in Figure 5. A selection of one item on every axis forms a token, which we write to a file. We then aggregate the data contained in these files to form a token sentence. This sentence matches one of the SASL videos on the memory card. We search the memory card using linear search because the videos are fetched randomly depending on the prescribed medicine. We find a particular video by performing linear search on the memory card and compare every string until we find the one that matches. The matching string is the name of the video and that is the video to playback for the Deaf user.

Layer 4 holds combinations of possible warnings and recommendations for the Deaf end user and uses the same algorithm as for Layers 1 and 2.

A Deaf patient reviews a prescription in a four-stage sequence. For videos in Layer 3, we recorded a limited number of complete sentences instead of tacking together fragments because they would not make sense in SASL. We concentrated on three factors: frequency, quantity and dosage event (see Figure 5). Selected values for the three parameters limit the pharmacist from making selections that are not pre-loaded.

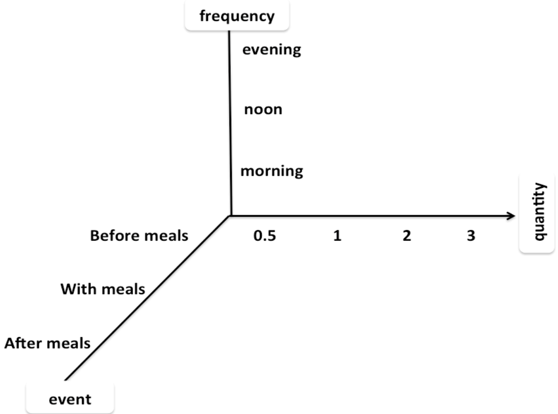

Figure 5 A three dimensional representation of the different permutations for a given prescription.

We store all SASL videos on the phone's memory card so as not to incur network costs. This means all communication is effectively limited to what has been stored on the phone.

VI. TESTING

We had sixteen participants for training and testing: eight semi-computer literate Deaf participants and eight hearing senior Pharmacy students. The sessions were conducted using role plays followed by individual questionnaires and then focus group discussions. We used SASL interpreters to collect data from the Deaf participants. The trial was video recorded from beginning to end.

We created a physical setting where a Deaf person visits a public hospital pharmacy at UWC. The focus was on usability testing including monitoring user interaction with the system, and identifying potential design flaws to be addressed in the next prototype. During the trial, researchers assisted none of the participants. Deaf participants were asked to input background information into SignSupport while they waited in line. Pharmacists waited at the counter as they normally do, and patients were called to the front to collect their medicine. When they got to the counter they produced SignSupport and handed it together with a paper prescription. The pharmacist (student) used the two items to dispense medication without directly communicating with the Deaf patient.

Both sets of participants we asked to answer a questionnaire that enquired about the usability of the software and also what they would like to improve. An informal discussion was held after the trial.

Pharmacists reported that SignSupport was easy to use. They suggested that it was much better to use SignSupport to dispense medicine to a Deaf patient. The average dispensing time using SignSupport was 4:23 minutes. In the first run of role plays, pharmacist's dispensed medicine without SignSupport and their average dispensing time was about 19:55 minutes per patient. Pharmacists reported that SignSupport was direct and to the point about giving explanations and instructions, and they were freed from those time-consuming tasks.

Deaf users were happy to use SignSupport for collecting medicine. They reported that it was easy to use and they would really use it in real life. Some Deaf users preferred to have the videos in colour but would still use SignSupport because the colour did not affect the legibility of the signing. All the participants accepted SignSupport, but they expressed concern that pharmacists would not accept the software at real pharmacies.

VII. FUTURE WORK AND CONCLUSION

Our goal in developing SignSupport is to help Deaf people at South African public hospital pharmacies to get the same quality of service as everybody else. We have shown that it is possible to build a software product that can work in a health domain to establish communication between a Deaf patient and a pharmacist with a guided set of questions in English for the pharmacist, and in SASL for a Deaf patient. SignSupport is not an expert system and does not use artificial intelligence techniques. A limited number of communication options are stored on a mobile phone, and this approach also avoids network data costs.

This paper has shown that it is possible to devise a solution that can improve communication between Deaf patients and pharmacists. SignSupport is not meant to replace interpreters or pharmacists, but is meant to be a communication aid. The reminders on the system can also help increase patient compliance and decrease incorrect adherence that Deaf patients are prone to. Before SignSupport can be used with actual medication, we must properly ensure that the correct videos are shown to Deaf end users.

Although SignSupport was designed, implemented and tested in a pharmacy context, the system could be modified and applied to any context, e.g. a police station or Home Affairs. This would entail an authoring tool to allow the system to be context independent.

VIII. ACKNOWLEDGMENTS

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