SignSupport: A Mobile Aid for Deaf People Learning Computer Literacy Skills

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Abstract: This paper discusses a prototype of a learning aid on a mobile phone to support Deaf people learning computer literacy skills. The aim is to allow Deaf people to learn at their own pace which in turn reduces the dependence on a teacher to allow weaker learners be assisted. We studied the classroom dynamics and teaching methods to extract how lesson content is delivered. This helped us develop an authoring tool to structure lesson content for the prototype. A prototype has been developed using South African Sign Language videos arranged according to the structure of pre-existing lessons. The technical goal was to implement the prototype on a mobile device and tie the resulting exported lesson content from the authoring tool to a series of signed language videos and images so that a Deaf person can teach him/herself computer literacy skills. Results from the user testing found the prototype successful in allowing Deaf users to learn at their own pace thereby reducing the dependence on the teacher.

1 INTRODUCTION

This paper describes our initial experience with a mobile prototype that supports teaching computer literacy skills to Deaf people, using South African Sign Language (SASL) as the medium of instruction. Deaf with a capital 'D' is distinguished from deaf or hard-of-hearing in that Deaf people use a signed language to communicate, thereby defining their culture much like other groups who use textual languages like English. Deaf people have limited literacy in spoken and written languages (Glaser and Lorenzo, 2007). Acquiring computer skills necessitates pre-existing knowledge of a written language. Learning involves simultaneously developing the written language whilst learning computer skills and technical terminology.

Bridging communication between Deaf and hearing people is an ongoing research area, for us we are extending to different communication contexts from previous SignSupport projects. All focus on constrained contexts where a limited collection of interactions were incorporated into pre-recorded SASL videos. The interactions previously investigated were between a doctor and a Deaf patient (Mutemwa and Tucker, 2010) and a between pharmacist and Deaf patients, (Chininthorn et al., 2012) implemented on a mobile phone (Motlhabi et al., 2013).

In this paper, we examine the context of adult computer literacy training. We investigate how to support Deaf people learning computer literacy skills using the International Computer Driving License (ICDL www.icdl.org.za) approved curriculum and the e-learner (e-Learner, 2013), developed by Computers 4 Kids (www.computers4kids.co.za). Currently, teaching Deaf learners involves the teacher reading instructions from the e-learner manual and signing the content to the learners. In the process, all Deaf learners must look at the teacher due to the visual nature of signed language. This approach inhibits the progress of faster learners since the pace of the class is dictated by the weaker learners because when something is unclear, all have to be interrupted.

Text literacy among Deaf people is only adequate for social purposes, between Deaf people who accept grammatical problems rather than specific and/or technical discussion (Glaser and Tucker, 2004). This inadequacy creates a communication barrier which hinders Deaf people from learning new skills. In developing regions, some Deaf people use services such as Short Message Service (SMS) and instant messaging applications such as WhatsApp to communicate with each other and with hearing people. Deaf people seeking higher education and employment opportunities are restricted due to limited text literacy. Many are unemployed or employed in menial jobs. This affects the socio-economic level of the community as a whole (Blake et al., 2014). SignSupport was evolved from assisting Deaf people communicate with pharmacists to supporting computer literacy learning in SASL. We partnered with a grassroots NGO, DCCT (Deaf Community of Cape Town) which is staffed by Deaf people and serves the needs of the larger Deaf community who primarily use SASL as their first language.

We conducted a field study and a user study, in two research cycles, with DCCT staff members to investigate how mobile phones could be used to support Deaf learners training in computer literacy skills. The purpose of the field study was to understand learning challenges that Deaf learners encounter at the task of learning computer skills and find out the existing technology capacity of the Deaf community. Based on the results we obtained, we designed and implemented our intervention, addressing some of the issues uncovered in the field study and evaluated the developed solution with DCCT staff members.

In the following sections of this paper, we highlight methods used towards improving Deaf literacy, the related work in mobile signed language communication and Deaf computer literacy projects in Section 2. We discuss our methodology in Section 3 and introduce our first cycle, the computer literacy classes, in Section 4 where we analyze the results. We introduce our intervention in Section 5, detailing the content creation in Section 6 and discuss the results obtained in Section 7. We conclude and outline the future work.

2 RELATED WORK

This section describes work related to SignSupport. We look at how literacy in Deaf adults has been developed and the work that others in the area of mobile communication technologies to support Deaf-related challenges.

2.1 Deaf Adult Literacy

Literacy development in adult Deaf populations has had its challenges both internationally and in South Africa. Internationally, the average reading age of Deaf adults is said to be at fourth grade level (Watson, 1999) and in South Africa, the average reading age of Deaf adults who have attended schools for the Deaf is lower than the international average (Aarons and Reynolds, 2003). In addition apartheid caused racial inequalities in educational development and provision resulting in varying literacy levels in Deaf people across different racial groups (Penn, 1990).

A *Bilingual-Bicultural* approach is where Deaf learners are taught through a signed language to read and write the written form of a spoken language (Grosjean, 1992). Other previous approaches to Deaf literacy such as the principle of Oralism (Lane, 1993) and total communication (Denton et al., 1976) approaches neglected the need for Deaf people to learn in their own language and promoted little literacy development. Research has shown that Deaf learners taught in sign language perform better than learners who are not taught this way (Prinz and Strong, 1998). An approach that aims to redress low literacy levels among Deaf Adults in South Africa where the use Deaf learners' existing knowledge of SASL and written English, highlighting the difference between these two languages in order to facilitate the development of their second-language skills in written English (Glaser and Lorenzo, 2007). In the case of Deaf learners, literacy is moving from a primary to a secondary communication form as well as moving from one language to another. We adopt the bilingual-bicultural approach to teaching computer literacy skills. By teaching the lessons in sign language, we use the Deaf learners existing knowledge (the known), to introduce computer literacy skills (the unknown).

2.2 Mobile Sign Language Communication

MobileASL is a video compression project that uses American Sign Language (ASL) as its medium of communication on a mobile device. The project was developed to enable Deaf users who use low to midrange commercially available mobile devices to send sign language video over a mobile network (Cavender et al., 2006). The aim for MobileASL is to make video communication possible on a mobile device without the need for specialised equipment like a high-end video camera, but instead to use standard equipment on the mobile device.

Cavender *et al.* conducted user studies to determine the intelligibility effects of video compression techniques that exploit the visual nature of sign language. Preliminary studies suggested that the best video encoders, at the time of the study, could not produce the video quality needed for intelligible ASL in realtime, given the bandwidth and computational constraints of even the best mobile phones. MobileASL concentrated on manipulating three video properties: bitrate, frame rate and region of interest (ROI) (Cavender et al., 2006). These properties were chosen as important for intelligible ASL on mobile phones. MobileASL provides the basis for intelligibility of video for sign language. For our study we choose to focus on the frame rate. Cavender *et al.* (Cavender et al., 2006) established that at frame rates below 10 frames per second (fps) signs were difficult to watch. As a trade-off we chose to use a frame rate of 25 fps.

MotionSavvy is a project that developed the UNI, a device that translates American Sign language (ASL) into audio and spoken word to text (MotionSavvy, 2014). The UNI uses advanced gesture recognition technology called Leap Motion (Motion, 2014) that allows users to see how their signs appear on camera which helps to make sure signs are input correctly and avoid missing important information (MotionSavvy, 2014).

2.3 Computer literacy projects

There are a number of projects that have sought to address increasing the educational level of Deaf and hard-of-hearing persons. To truly meet the needs of users, in addition to providing guidelines based on technology, it is necessary to understand the users and how they work with their tools (Theofanos and Redish, 2003). One of the solutions can be in providing additional educational input using multimedia-supported materials on the World Wide Web (Debevc et al., 2007). This kind of user interfaces can be found in other projects such as BITEMA (Debevc et al., 2003) and DELFE (Drigas et al., 2005). Results from these projects have shown that multimedia systems additionally increased the success of learning.

Project DISNET in Slovenia, focused on providing an alternative way of learning computer literacy using accessible and adapted e-learning materials. It used multimedia materials in a web-based virtual learning environment. The aim of the project was to increase computer literacy among Deaf and hard of hearing unemployed people using the ICDL e-learning material (Debevc et al., 2007). The system was designed for people who have access to computers, high speed broadband Internet but without basic computer or web browser experience.

The projects above are concerned with e-learning materials and e-learning environments and rely on the World Wide Web to support their multimedia materials. The commonality between our work with the projects above is the use of multimedia learning materials.

2.4 Discussion

SignSupport emphasizes video quality and resolution much like MobileASL but differs in terms of over-the-air data charges. The videos are stored locally on the phone. Data costs in South Africa are higher than in neighbouring African countries (Calandro et al., 2014), making it uneconomical for Deaf people and further marginalising them. Similar to project DISNET, SignSupport uses multimedia ICDL learning materials to improve computer literacy education levels amongst Deaf people. It differs in terms of not being web-based utilizing broadband internet connections. SignSupport is mobile-based and uses commercially available devices.

3 METHODOLOGY

SignSupport is based in over a decade of research and collaboration by an interdisciplinary team comprising a diverse range of expertise. All members were involved continuously through the project.
Deaf users play a steering role in the research. They dictate how they would use it and most of the user requirements are gathered from them by integrating their perspectives thereby increasing chances of an accepted solution.
A Deaf education specialist who is a link between the technical team and the Deaf community members and also the facilitator for the computer literacy course. The specialist assists in design and explanation of Deaf learning practices to make SignSupport fit Deaf users' expectations and helps translate the course material into SASL.
Computer scientists who are tasked with implementing the design of SignSupport and to verify that the SASL videos were shown in the correct and logical manner. They examine how end users engaged with SignSupport to uncover design flaws and any other interesting outcomes.
We undertook a community based co-design process (Blake et al., 2011) following an action research methodology. This approach required participation with the target groups and engaged them throughout the design, implementation and evaluation phases and referred back to them to show how their feedback is incorporated into SignSupport. During all interactions with Deaf participants, the facilitator who is acceptably fluent in SASL facilitated the communication process which aided us in understanding the usage context and building positive relationships with the Deaf community.
We undertook two research cycles. In the first cycle

we observed and participated in the computer literacy classes at DCCT where some of their staff members were taking the classes and conducted unstructured interviews with the facilitator in the form of informal conversations and anecdotal comments made by the facilitator during the class sessions. Data were gathered using hand written notes and photographs were used to build a cognitive system (Hutchins, 2000) of the computer literacy classes using a distributed cognition approach. The ideas generated were then used to synthesize our solution intervention.

We collaborated with two other researchers to co-design an XML specification that is used to structure lesson content and is generated by a content authoring tool. The XML specification was an abstraction of the hierarchical structure of the e-learner manual. A mobile prototype was developed that used the XML specification and mapped the content of the e-learner and serially displayed the content in SASL videos and images. The mobile interface design was inspired by the work of Mothlabi (Motlhabi, 2013) such that the video frame size covered at least 70% of the display size and the navigation buttons and image filled up the rest of the space.

We recorded SASL videos of two lessons chosen from the e-learner curriculum using scripts that we created and videos that were stored on the mobile phone's internal memory. The mobile prototype was then evaluated in a live class setting and the results were taken into account for the next design.

4 COMPUTER LITERACY CLASSES

The computer literacy classes are taught using the International Computer Driving license (ICDL) approved curriculum, e-Learner (e-Learner, 2013), which has two versions: school and Adult. The Adult version is taught at DCCT. The aim of the classes is to equip Deaf learners with computer skills that will result in the learners taking assessments to get the e-Learner certificate. The Deaf learners then progress to the full ICDL programme. The computer literacy classes (e-Learner classes henceforth) are taught by a facilitator who has been in a long involvement with DCCT in addition to collaborating with researchers from the University of Cape Town (UCT) and the University of the Western Cape (UWC) in the SignSupport project.

The Deaf learners were all DCCT staff members. Three were female and two were male with an average age of 38.4 years. Three of the learners had received the EqualSkills certificate (EqualSkills, 2014) prior to beginning the e-Learner classes. EqualSkills is a flexible learning programme that introduces basic computer skills to people with no prior exposure.

4.1 Course and Lesson Structure

E-learner is a modular and progressive curriculum spread over seven units. The units are similar to the modules in the ICDL programme but contain less detail. The e-learner curriculum is in two parts: a manual containing lesson instructions used by the facilitator and software, loaded on to the computers that the Deaf learners use to retrieve templates and lesson resources. The seven units of the e-Learner are: IT Basics, Files and folders, Drawing, Word processing, Presentations, Spreadsheets and Web and Email essentials. The Deaf learners use computer applications to complete the templates following signed instructions from the facilitator. The facilitator first teaches literacy skills in the written language to develop their technical vocabulary.

These units are composed of lessons that have the same structure in the following categories: Orientation, Essential and Supplementary. Lessons in different units overlap i.e the same lesson appears in different units. This allows for the learner to revise a lesson or skip it having done it before. The lesson structure is as follows:

1. Integrated activity – A class discussion on the lesson content.
2. Task description – A brief overview of the work the learners will perform.
3. Task steps – The individual tasks that the learners perform to complete the lesson.
4. Final output – A diagram showing what the learners are expected to produce after performing the task steps.

4.2 Classroom setup

In the computer lab there are six computers in a U-shaped arrangement. There is a server at the front left of the classroom with a flip-board on a stand and two white boards. The arrangement is ideal to allow the learners to have a clear line-of-sight to view the front of the classroom where the facilitator stands and signs. The seating arrangement also allows the Deaf learners to see each other which is crucial for class discussions and to see contributions from other learners and questions.

Each computer, except for the server, is running a copy of Microsoft Windows 7. All computers have a copy of Microsoft Office 2007 and e-Learner Adult version 1.3.

4.3 Results

In observation and participation in the e-Learner classes we uncovered various themes that are discussed below.

The teaching of lessons varied. Although the lessons in the e-Learner manual had the same structure, the facilitator adapted the teaching method and lesson content to make it relevant for the Deaf learners. Teaching generally takes up a whole lesson and the Deaf learners only get to perform the tasks in the next class session which would be the following week.

Images played an important role in teaching. The facilitator made use of a data projector to display open documents in either Microsoft Word or Powerpoint. There were numerous times where the facilitator pointed at the projected image of the computer application that was being used in the lesson, pointing out buttons and icons and lists to scroll through.

Teaching the Deaf learners is demanding and tiring for the facilitator. There is one copy of the e-Learner manual used for the lessons because the Deaf learners are text illiterate, unable to read the English text in the manual. The facilitator has to read the instructions, understand them before signing the instructions to the Deaf learners in SASL. In other instances, the facilitator has an assistant who voices the instructions to the facilitator who then signs them to the Deaf learners.

In order to gain the attention of all the Deaf learners, the facilitator waves her hands in front of the learners. This is necessary in order to explain a concept or give instructions to the Deaf learners due to the visual nature of sign language. This is a distinguishing factor between Deaf and hearing learners called divided attention. Hearing learners can simultaneously listen instructions being given and look at their computer monitors without looking up. Deaf learners cannot watch the SASL signing and look at their computer screens at the same time. Eye contact first has to be gained before signing can begin.

Deaf learners use SASL as their principal language of communication and it has its own structure and vocabulary. English users bring all the necessary vocabulary to the task of computer literacy skills learning. Deaf learners do not have this vocabulary to rely on, hence they are learning English vocabulary and ICT skills at the same time. English vocabulary in computer literacy classes has to be broken down by either making use of synonyms, definitions or descriptions. For example, in a lesson observed, the facilitator broke down the word “duplicate” into the phrase “make a copy” after which the Deaf learners associated copy with its respective sign in SASL.

We observed different work rates of the Deaf learners during our class participation, similar to hearing learners. The difference is that Deaf learners have the additional burden of having to stop and look at the facilitator for instruction. All need to be interrupted to see signed instruction. This would interrupt the whole class and the learners work rate. The faster learners usually finished their tasks earlier and often spent time waiting for the slower learners to catch up. The pace of learning as a result, was dictated by the slower learners as the facilitator was forced to teach at a slower pace to accommodate the slower learners. This puts pressure on the slower learners and makes it boring and at times frustrating for the faster learners. The faster learners were the same three Deaf learners, previously identified, who had acquired EqualSkills certificates.

We also observed the Deaf learners using various mobile phones. These phones ranged from feature phones to smartphones. One learner had two smartphones: a HTC running Android OS for work and a Blackberry for personal use. Two other participants had Nokia feature phones with QWERTY keyboards. These devices are capable of playing video as well as instant messaging applications such as WhatsApp. In addition, the Deaf learners do not have computers or laptops at home and at work, they use old computers hence their limited experience.

4.4 Analysis and design implications

We use a distributed cognition approach (Rogers et al., 2011, p.91) to understand the e-learner class environment. Distributed cognition studies the cognitive phenomena across individuals, artefacts and internal and external representations in a cognitive system (Hutchins, 2000) which entails:

- Interactions among people (communication pathways).
- The artefacts they use.
- The environment they work in.

We define our cognitive system as the e-learner class where the top-level goal is to teach computer skills to Deaf learners. In this cognitive system we describe the interactions in terms of how information is propagated through different media. Information is represented and re-represented as it moves across individuals and through an array of artefacts used (e.g. books, spoken word, sign language) during activities (Rogers et al., 2011, p.92).

Propagation of representational states defines how information is transformed across different media. Media here refers to external artefacts (paper notes, maps, drawings) or internal representations (human memory). These can be socially mediated (passing a message verbally or in sign language) or technologically mediated (press a key on a computer) or mentally mediated (reading the time on a clock) (Rogers et al., 2011, p.303).Using these terms we represent the computer literacy class cognitive system showing the propagation or representative states for the teaching methods.

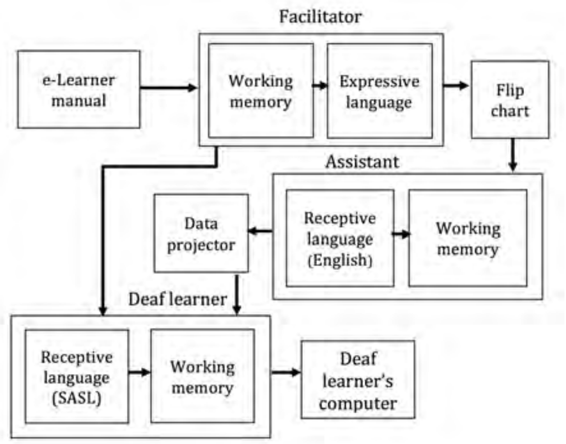

Figure 1: A diagram showing the propagation of representational states for the teaching method to deliver a single instruction to the Deaf learners. The boxes show the different representational states for different media and the arrows show the transformations.

By representing the teaching method in the diagram (see Figure 1) we discover the task of teaching Deaf learners is far from being a simple task, involving a set of complex steps. Instructions are propagated through multiple representational states, verbally when interacting with the assistant, visually when interacting with the Deaf learners and mentally in both cases. In comparison with Figure 2 where the representational states are fewer, our proposed system attempts to bring the Deaf learners closer to how hearing literate people learn. The design implications would be to reduce the number of steps involved to deliver instructions to the Deaf learners. A solution would be to deliver the lesson instruction in SASL videos and images, effectively removing a number of representational states, approximately four. These SASL videos are pre-recorded and contain the lesson instructions from the e-learner manual thereby eliminating the need for the assistant and the facilitator to deliver the lesson instructions. In addition, limited text literacy amongst the Deaf learners means the need for

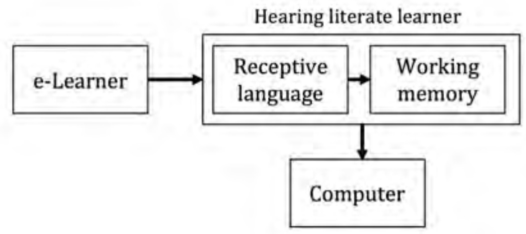

Figure 2: The diagram shows the propagation of representational states for a hearing literate person. The boxes show the different representational states for different media and the arrows show the transformations.

SASL instructions thereby allowing them to learn in their preferred language.
Mobile phones provide an ideal way to deliver the lesson content and most Deaf people use a mobile phone to communicate with other Deaf and hearing people (Chininthorn et al., 2012). This solution should work on off-the-shelf mobile phones similar to the previous SignSupport solution. Therefore, SignSupport could be carried home by Deaf learners on their cellphones and where they can get access to a computer teach themselves. In addition, the socio-economic situation of the Deaf learners put them in position not able to afford the high data costs. This eliminates use of data networks to transfer the lesson content or host the videos externally and stream them to the mobile phones.
Another design consideration is to organise and structure the SASL videos to represent the logical flow of the lessons in the e-learner. This would involve design of a data structure that would effectively structure the course and lessons to reflect the e-learner manual. Discussion of the design is in the following section.

5 DESIGN AND IMPLEMENTATION

In this section we discuss the technical details of the design of the data structure, the design of the content authoring tool and the user interface of the SignSupport mobile prototype. This paper presents the first version of SignSupport that has undergone its first iteration.

5.1 Structuring Lesson Content

For SASL videos and images to be meaningful, they need to be organized in a logical manner that reflects the e-learner lesson structure (see Section 4.1).

The analysis of the e-learner classes revealed the numerous number of steps involved to deliver lesson content to Deaf learners. To model the structure of the e-learner curriculum we chose Extensible Markup Language (XML) (W3C, 2014) as our data format. XML provided the necessary flexibility to represent the curriculum in its hierarchical structure. To manage the lesson resources (SASL videos and images) we chose to use Universal Resource Locators (URLs) that would point to the location where the resource was stored. XML represents data in text in a human readable form between opening and closing tags. To represent the e-learner structure we followed the procedure below:

1. Identify the course, unit and lesson structure.
2. Represent the course, unit and lesson using the tags (course, unit and lesson).
3. Provide the course, unit and lesson with unique identifiers.
4. Identify the sections of the lesson and provide them with tags.
5. Identify what lesson sections are to be represented using video tags
6. Identify what lesson sections need images to accompany the videos and represent them using image tags.
7. Identify how to manage lesson assets (images and videos).

Using the above procedure we abstracted the e-learner hierarchical structure representing the course, unit and lesson with unique identifiers *course_id, unit_id* and *lesson_id* respectively. Titles for the course, unit and lesson were represented using *course_title, unit_title* and *lesson_title* respectively. Lessons had the extra XML tag, *lesson_type* that identified the category (Orientation, Essential or Supplementary) in which the lesson was housed. The resulting XML structure is shown in Figure 3.

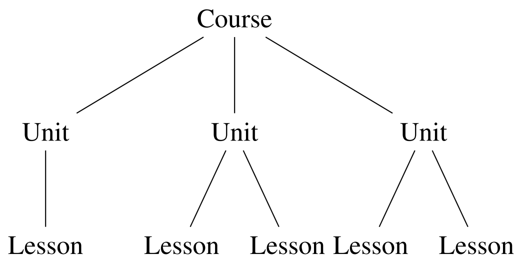

Figure 3: The XML structure of the course.

The e-learner curriculum changed infrequently making it beneficial to store the resources locally on the device. This effectively make the system independent of data networks to update the lesson content. In order to manage the lesson assets and the XML lesson files effectively we decided to store all in the folder structure. The root folder was named *SignSupport*. In that folder, there were three subfolders:

- *xml* – This folder stored XML data files of the lessons.
- *video* – This folder stored all the SASL video files.
- *shared_images* – This folder stored images that are used in the lessons.

This XML data structure is parsed using built-in XML parsers used by the mobile prototype (see Section 5.3).

5.2 Content Authoring Tool

We needed to design a content authoring tool that would structure the lesson content. It would allow domain specialists such as the facilitator to create content for their usage context without the need for a programmer. Mutemwa and Tucker identified this as a bottleneck to their SignSupport designs (Mutemwa and Tucker, 2010), limiting their design to one scenario within the communication context.
The design was modelled on the structure of the e-learner manual (see Section 4.1). It uses drag-and-drop features to add lesson resources (videos and images) to the placeholder squares that represented the lesson description, task description and task step as shown in Figure 4. Lesson resources are uploaded to the authoring tool and displayed in panels on the right. Once a lesson is created and lesson resources added, it can be previewed to view the lesson in sequential order from the beginning. The lesson is then added to a unit and a course before saving and exporting the course. Exporting the course generates the XML data structure that then consumed by the mobile prototype below (see Section 5.3).
The authoring tool was implemented using Java FX (Oracle, 2014), a user interface framework, using Netbeans 7.4 integrated development environment (IDE). It was tested on both Microsoft Windows 7 and Apple Mac OS X 10.9.5 to check for compatibility.

5.3 Mobile prototype

We chose to investigate whether mobile devices were a viable means to support Deaf learners because of their ubiquitous nature.
The mobile phones we used had 25 gigabytes (GB) of internal storage space, with a touch sensitive display

Figure 4: The content authoring tool interface that allows the facilitator to create lessons for Deaf learners.

of size 4.8 inches and a resolution of 1280 by 720 pixels. The phones run Android OS 4.3 (Jelly bean). The higher resolution screen was considerably larger than the display used in the previous version of SignSupport (Motlhabi et al., 2013). Our version of SignSupport was only similar in video playback interfaces but differed in content structure and context of use. The extra space allowed for an image to be inserted below the video frame in addition to the navigation buttons (see Figure 5).

Figure 5: The SignSupport interface with an image of an icon beneath the video and video caption in the action bar which indicates the instruction the learner is currently working on.

Navigating the mobile prototype interfaces is done in two ways: linear and hierarchical navigation. To navigate linearly a Deaf learner uses the next and back buttons on the lesson detail screen shown in Figure 5 to move from one video instruction to another. The linear structure navigates through the XML structure (see section 5.1) that was generated from the content authoring tool in section 5.2. Hierarchical navigation is done moving from the home screen down to the lesson detail screen and back shown in Figure 6. To move down to the lesson detail screen, the Deaf user starts on the home screen and selects a lesson from the list of lessons (see Figure 7) by pressing on the list item that has the lesson name. Once a lesson is selected, the Deaf learner is presented with another list of lesson sections where the learner clicks on a list item to reveal the screen shown in Figure 5 that contains the SASL video instructions. The depth of the hierarchical navigation was at most two levels from the home screen for a better user experience.

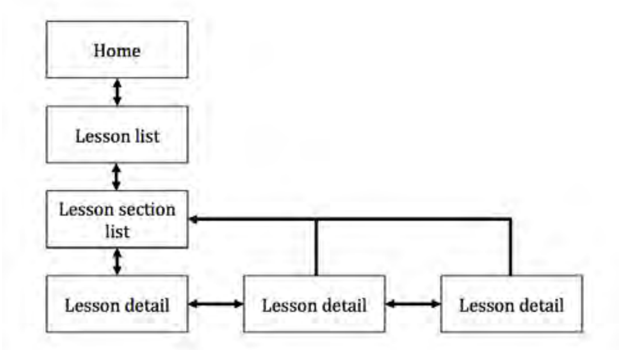

Figure 6: User interface navigation on the mobile prototype of SignSupport. The boxes represent the different screens the user interacts with and the arrows indicate the direction of navigation between the screens.

Figure 7: User interface navigation on the mobile prototype of SignSupport. The interface shows the lesson sections in a scrollable list. The Deaf learner taps on the desired list item to reveal the screen with the SASL video instructions.

In the backend of the mobile prototype, the XML data format designed in Section 5.1 was parsed using the Android interface *XmlPullParser*. XML files stored in the SignSupport folder in the mobile phone internal memory are modelled using an ArrayList data structure. Navigation is facilitated using clickable list widgets and buttons on the interface and scrolling through

the list of lessons and lesson sections (see Figure 7) was done through swipe gestures.
The mobile prototype is designed to be used concurrently with a computer as a tutoring system. The Deaf learner can query the facilitator if further clarification is needed. and when in the presence of a facilitator. It

6 CONTENT CREATION

We recorded the SASL videos with the help of a SASL interpreter. Recording was done in a room with sufficient lighting. The SASL interpreter stands in-front of camera mounted on a tripod. The attire worn by the interpreter was neutral to contrast with the background colour. The interpreter we chose met the following criteria:

1. A registered SASL interpreter.
2. A background in education.

Before recording the videos, we created a conversation script. The script detailed the instructions, in bullet point form, for the e-learner lessons. We chose two lessons from the e-learner manual and created conversation scripts for them. To generate the conversation script the original instructions of the lessons were first written down. The facilitator guided us with the abstraction of the lesson content by insisting that instructions have one task or a single explanation per bullet point. Multiple instructions were broken down to single tasks and single explanations and computer terminology explained further in detail. In some cases synonyms for complex terms were used instead. For example the word *duplicate* was replaced with the phrase “copy and paste” where signs for them existed in SASL. This was repeated until all instructions were done and simplified.
The recording procedure involved having an interpreter being voiced the instructions on the conversation script. The interpreter then signs on camera until all the instructions on the script have been translated into SASL. Signed instructions are separated by writing down the number of the instruction on a whiteboard or paper according to its position on the script and displaying it in-front of the camera while continuous recording. When the interpreter puts her hands down, that is the visual cue that the signing for that particular instruction has ended which helps when editing the SASL videos.
The recorded SASL videos were edited in Adobe Premier Pro CS6 where the audio channel was removed to reduce video file size. The resulting videos were encoded using the H.264 video codec with a frame size of 640 x 480 pixels and a frame rate of 25 frames per second (fps) as per the ITU requirements (Hellström, 1998). We converted the original video files from MPEG2 (.MPG extension) to MOV before editing using Quicktime pro because MPEG2 compression is cumbersome to use. The final video had MPEG-4 video compression that was compatible with Android OS and the official video format for the platform. The resulting video clips are short, the longest video clip is 48 seconds which does not pose a high cognitive workload on the learner.

7 EVALUATION

This section analyses the results obtained from our user evaluation of the mobile prototype. We observed the Deaf learners to uncover design flaws and any other interesting use of the prototype.

7.1 Procedure

Five DCCT staff members participated in the evaluation. These were the same Deaf learners in section 4. The facilitator was present to interpret on our behalf. The Deaf participants were each given a smart phone that contained the prototype. After a short briefing about the project, the Deaf participants were first trained how to use the system then given a practice lesson to do for 20 minutes to get a feel of using the prototype and a second lesson to do for 30 minutes. In the first lesson, the learners were required to pair graphics of special keyboard keys (e.g Space bar, Shift key etc.) with images that represent their function. The second lesson required the learners to identify and name different storage media. Then, identify which files represented by icons could fit into the storage media without exceeding their capacities. Both lessons were provided in Microsoft Excel templates. After, the Deaf participants were invited to participate in a focus group discussion to get their opinions and feedback on the prototype. The session was video recorded and photographs were taken with the help of an assistant.
Questionnaires were not used to elicit feedback on the system. Motlhabi noted that conducting an evaluation with Deaf text semi-literate participants proved to be a problem while answering questionnaires (Motlhabi, 2013). The two SASL interpreters available to interpret the questionnaires questions for the eight Deaf participants caused a bottleneck as some participants had to wait for the interpreters to finish helping other participants. In addition, employing more SASL interpreters was not feasible because of how rare and expensive they are in South Africa.

7.2 Results and analysis

The number of representational states involved in delivering a single instruction reduced by 4. It eliminated the facilitator, flip chart, data projector and assistant states involved in the process shown in Figure 8. The reduced representational states moved the Deaf participants closer to hearing literate users.
The participants had little difficulty navigating the user interface. Two participants had difficulty locating the back button on the interface that navigated back to the list of lesson sections even after training. All the participants found it easy to re-watch the SASL videos. It was easy for them to use a tap on the video frame to bring up the video controls to replay the video. They also found it easy to navigate through the lesson content using the back and next buttons on the interface as well as navigate between the list of lesson sections and the lesson detail screen that contained the SASL videos.

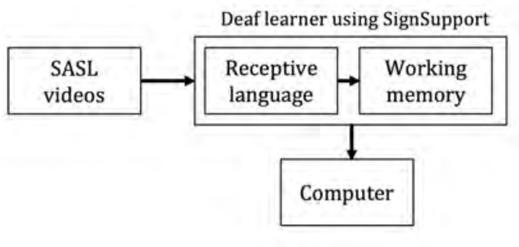

Figure 8: The representational states of a single instruction being delivered to a Deaf learner using SignSupport. The reduced states make it simpler for Deaf learners and promotes individual work.

All the participants noted that some signs used in the videos was different to theirs, indicating dialectal difference in the signs used in the SASL videos. Despite the difference, the stronger participants were able to understand the context of the instructions and continue with the tasks. In this case potentially stronger participants helped the weaker participants understand the instructions in 18 instances observed.
We also observed, during the testing, that the Deaf participants were individually working at their own pace, and the facilitator helped the participants individually in 21 different instances. Two of the 21 instances of assistances were initiated by the Deaf participants while the other 19 were initiated by the facilitator. In 9 out of the same 21 instances, the facilitator prompted a Deaf participant to continue with the task, click on a button or replay a video. In the other 12 instances, the facilitator explained unclear instructions in SASL. The assistance did not affect the other participants working individually and the role of the facilitator changed from delivering the lesson content to a support role. Consequently, the workload on the facilitator reduced.
Some Deaf participants noted a mismatch between the instruction and what they expected to see on the computer. The mismatch occurred due to unforeseen steps such as the monthly password that is entered in the software to access the lesson content. The facilitator reported that additional SASL videos with contextual information and discourse markers (Sharpling, 2014) were needed to provide cues for the Deaf participants to progress to the next instruction or to perform a task.

8 CONCLUSION AND FUTURE WORK

Deaf people with low text literacy stand to benefit from having SignSupport to facilitate them learning computer literacy skills in their preferred language, South African Sign Language (SASL). This paper has discussed the challenges of text illiterate Deaf people learning computer skills dependent on the facilitator using one e-learner manual. Using the distributed cognition approach revealed the cognitive load and the number of representational steps that were involved in delivering a single instruction to Deaf learners. The prototype design implemented on commercially available mobile devices has shown promise to support Deaf users learning computer literacy skills by having content in SASL videos. We observed that the prototype allows for Deaf users to work individually at their own pace, with or without the assistance from the facilitator thereby reducing the workload on the facilitator. We also mentioned the design of an XML data format that organised the SASL videos and images in a logical way to represent the lesson. The findings from this work are being used to improve the design of the prototype and verify the SASL videos to address instructional inconsistencies.
Future work could investigate whether the SignSupport effectively increases computer literacy skills among Deaf people. This would involve a pedagogy study with Deaf learners with pre-existing basic computer knowledge.

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