Building and evaluating an Android mobile App for people with hearing disabilities in Saudi Arabia to provide a real-time video transcript: a design science research study

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Abstract: Hearing loss or deafness affects the daily lives of many people around the world. One of the issues that people who are deaf or hard of hearing face is the difficulty in understanding the audio content of the videos they are watching. This study proposes an Android app to assist individuals with hearing disabilities in Saudi Arabia by providing transcript displays for any video uploaded into the App. A three-cycle design science research (DSR) methodology was adopted for this study, and the app was developed according to the agile software methodology, Scrum. The "asmeany" app was evaluated within two stages, focusing on sociotechnical and technical performance perspectives to assess the app's usability and utility. The usability of "asmeany" was evaluated by ten deaf people from Saudi Arabia using A-SUS, with /encouraging results. When the app's utility was evaluated using unit testing, all the stories and scenarios passed; thus, the app is error free and performs as expected. As a result of this DSR project, three design principles are recommended for use in building any IT artifact for deaf people or those with hearing loss.

Keywords: hearing disabilities, deaf, app, DSR, real-time video transcript.

1. Introduction

Hearing loss is a term used by health care professionals to refer to a reduction in the ability to hear to below normal threshold levels. Hearing is measured by the level of decibels (dB) necessary for a subject to notice and understand audio signals; the higher the dB necessary before sound is heard, the less a person can hear. The severity of hearing loss in dB is graded into five levels: mild, moderate, moderately severe, severe, and profound (Shearer et al., 2017). According to the World Health Organization (2020), 466 million people have disabling hearing loss, which is around 6.1% of the global population. By 2050, this number will increase to approximately 900 million people, equal to one in every ten people (World Health Organization, 2020). Furthermore, according to the Center for Strategic and International Studies (2014), of the 350 million people in the Middle East, around 11 million have disabling hearing loss. Hearing loss impacts an individual's ability to communicate, causing sufferers to feel loneliness, frustration, and isolation (World Health Organization, 2020).

Watching videos is becoming increasingly necessary for everybody, regardless of age, gender, and culture. Millions of videos are posted and watched online on platforms such as YouTube or TikTok. YouTube is the second most visited website globally, with 1,300,000,000 users. Everyday, an average of 300 hours of videos are uploaded, and five billion videos are watched (MerchDope, 2020). With two billion users, the TikTok platform is one of the most downloaded social media apps from the Apple store and Google Play (Mohsin, 2020). Around 68% of the TikTok users watch other people's videos, while 55% upload their own (Beer, 2019). These videos are for education, entertainment, or other purposes.

Unfortunately, there are evident problems for people who are deaf or who have varying levels of hearing loss, particularly when trying to watch certain videos. According to disability experts in Florida, one of the everyday difficulties that people with hearing loss or deafness face is the inability to go to the movies and watch the newest films with subtitles. Furthermore, most videos are uploaded without subtitles or transcripts, adding to difficulties for people with hearing problems. In the Middle East, in particular, there is a lack of tools that provide immediate transcripts for Arabic videos. Providing video transcripts could assist Arab people with hearing loss in becoming more involved in the community by simplifying their lives; this is the focus of this design science research (DSR). According to Hevner & Chatterjee (2010), DSR is a research paradigm that assists researchers in answering or solving a human-related question or problem through the creation of an IT artifact. The design cycle in this paradigm

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mainly consists of two phases: build and evaluate. As Hevner & Chatterjee (2010) stated, knowing and understanding the problem and the solution are the fundamental principles of DSR when building an IT artifact. This research aims to satisfy the following objectives:

(1) Build a free Android mobile app that provides Arabic and English video transcripts for people in Saudi Arabia who are deaf or have hearing loss.

(2) Evaluate the mobile app in two stages from sociotechnical and technical performance perspectives.

Achieving these goals would improve the quality of life for deaf individuals or those with varying levels of hearing loss by simplifying watching social media content, which reduces their feelings of loneliness and isolation. The rationale for this work is that smartphone apps have been explored as a solution for a variety of challenges, including helping people with disabilities. These apps have received scholarly attention worldwide because of their positive impact, and the number of people using these apps has increased globally (Kacetl & Klímová, 2019; Convery et al., 2020). Furthermore, apps are considered possible tools for breaking communication barriers experienced by the deaf or hard of hearing (Alnfiai & Sampali, 2017). Supportive apps provide access to essential services and are especially helpful when participating in social media, as this has become a significant part of most individuals' daily activities.

This research paper is based on the three cycles in DSR: relevance, design, and rigor (Hevner & Chatterjee, 2010). We also followed an agile software development method, the scrum framework, in the building phase to ensure the creation of high-quality products (Darwish & Megahed, 2016) and used Google's Speech-to-Text recognition to provide the video's transcript to users. The "asmeany" app was evaluated in two stages. In the first stage, the authors measured the prototype's usability using the Arabic System Usability Scale (A-SUS), focusing on the sociotechnical perspective. Ten deaf people watched a video of the "asmeany" prototype and then answered the A-SUS questions. The A-SUS score was 71.5, indicating that the prototype is useful. After building the final app, and during the last design cycle, we evaluated the utility of "asmeany" using unit testing, concentrating on the technical performance perspective. The results for all the stories and the scenario were passes/positive/satisfactory, indicating that the app is error-free and matches our expectations.

This artifact is novel because it provides a real-time transcript for any uploaded video. Thus, a significant amount of time and effort in understanding the video's audio content is reduced for people with hearing disabilities. Additionally, using this app will help people with profound hearing loss or who are deaf become more involved in society. According to Gregor & Hevner's 2x2 grid for knowledge contribution (Gregor & Hevner, 2013), this app fits in the improvement portion because it focuses on developing a new solution for a well-known problem.

This research article is organized as follows: Section 2 mainly discusses some related works. Section 3 presents the research approach and methods that this research applied, consisting of two other subsections (the building and the evaluation of technology artifact "asmeany"). Finally, in section 4 any limitations, and future works and concludes this research article.

2. Related works

Information and Communication Technology (ICT) has been widely used to improve the quality of the lives of people with visual (Mora-Lezcano et al., 2019), hearing, and mental disabilities (Hababeh et al., 2020). ICT solutions dramatically improve the lives of individuals with hearing disabilities who can use technology such as educational applications, captioning systems, computer-based note-taking, and hearing aids, to name a few, in their everyday activities (Yue & Zin, 2013). Yeratziotis & Van Greunen (2013) compiled a list of guidelines for designing mobile apps for people who are deaf or hard of hearing. The list was compiled by investigating different guidelines and heuristics, such as the guidelines for telecom accessibility, usability heuristics by Jakob Nielsen, and deaf accessibility features used by manufacturing companies such as Apple, Samsung, and Google Android. Yue & Zin (2013) proposed a model based on Pugh's product development process (PDP) model to design and implement a game mobile app for teaching deaf and hard of hearing children. Pugh's PDP adopts an iterative

design process that consists of the market, specification, concept design, detail design, manufacture and sell stages of design. The proposed app includes voice recognition, a database with the required contents, and a multimedia interface with the 3D images of objects to be learned with sign representation. The focus of the study was on strategies based on established behavioral change theories. These strategies include increasing learning interest, supporting motivation, fostering self-efficacy, and influencing the attitudes toward the study of people with disabilities. Mahamud & Zishan (2017) proposed a wearable watch-like assistive device to allow individuals with hearing disabilities the ability to communicate with people within proximity. The device is connected to an Android app and converts voice to readable text displayed on the screen of the wearable device.

Many applications have been developed to simplify the lives of people who are deaf or hard of hearing. Some of these apps are intended just for transcribing purposes and focus on records rather than videos. Some applications support video transcripts, but they are either not free or only support Arabic or English. For example, the Transcribelt app is an Android mobile app that converts audio into text, including WhatsApp speech messages. The user just chooses the file, and the app will convert it into text quickly. The Transcribelt app supports several languages, including Arabic (Apkpure, 2020).

Another example is the Live Transcribe & Sound Notifications app for Android mobile devices (Google play, 2020). This app converts real-time speech, conversation, and sound into text and saves it for three days via Google's automatic speech recognition and sound detection technology. It is free and supports more than 80 languages, including Arabic and English (Google play, 2020). A third example is Temi, which is not a free app, which converts speech and video into text (Google play, 2020). A fourth example is the Hodhod app which only supports Arabic language users. It provides several free services for Arab people with hearing disabilities by providing support such as sign language for some educational and entertainment videos. However, the Hodhod app is not customized, which means that users cannot upload their own videos (App Store Preview, 2020). The following table shows the main features of all the above-mentioned apps, including the "asmeany" Android app:

Table 1. Comparison of "asmeany" and Other Apps

Features	**Transcribelt**	**Live Transcript & Sound Notifications**	**Temi**	**Hodhod**	**"asmeany"**
Video Transcript	No; just audio	No; just audio	No; just audio	No; sign language	Yes
Supports many languages (inc. Arabic & English)	Yes	Yes	Just English	Just Arabic	Yes
Cost	Free	Free	Paid	Free	Free
Easy to use	Yes	No	Yes	Yes	Yes
Copy and paste any transcript	No	No	No	No	Yes
Saves transcripts	No	Yes, for three days	No	No	Yes

As smartphone users increasingly enjoy mobile apps, developers and researchers alike are spending a large portion of the development process evaluating the app's usability. Usability, as defined by ISO, is "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of us" (Mathur et al., 2018). User experience (UX) is another concept that is widely adopted in evaluating usability. UX, as defined by Norman & Nielsen (2021), it is a process that "encompasses all aspects of the end-user's interaction with the company, its services, and its products.". Kumaran et al. (2019) conducted a systematic literature review to analyze the different options for an optimal deaf usability evaluation model for an

M-banking application. Their results identified four dimensions for evaluating such an app, namely: efficiency, effectiveness, satisfaction, and accessibility. Mathur et al., (2018) proposed a usability evaluation framework that focuses on code-related usability issues. A code-related usability issue is a functional guideline as opposed to non-functional guidelines. For example, the guideline "Password field should reveal password in clear text" (Nielsen & Budiu, 2015) is a functional guideline, while "Label button in a descriptive way" (Nielsen & Budiu, 2015) is a non-functional guideline. The framework employed a code analysis approach composed of four major parts; a decompilation component, a validation test case generator, a validation execution engine, and a recommendation engine that offers code snippets for unmet guidelines. The framework was tested on an Android app, and it was evaluated by 16 app development companies in India. The results showed that 81% of the developers found that the framework and the setup were easy to follow.

A-SUS, Arabic-System Usability Scale, used in this study was developed by (AlGhannam et al., 2018), representing an Arabic translation of the widely used System Usability Scale SUS. SUS is a 10-question questionnaire that is used to assess the usability of various systems and applications. SUS exhibits many favorable features, as stated in (AlGhannam et al., 2018), including its wide acceptance, robustness, and reliability with even a small number of participants. Five professional translators conducted the translation process. Then, the translations were presented to an Arabic linguistic professor for further examination and assessment until an agreement was reached. To assure accurate translation, the Arabic questions were backtranslated to English, and the result was contrasted with the original English questions. A-SUS was evaluated empirically on students in the Department of Communication Disorders Sciences in an Arabic university and showed an acceptable result in measuring mobile applications' usability. SUS was used by (Botella et al., 2018) in evaluating the usability of an augmented reality app for teaching chemistry in a secondary school. The experiment was conducted by recording sessions of the students while using the app. The students were given tasks to be performed, such as writing a chemical formula in the app to see its molecular structure. To evaluate the effectiveness and efficiency of the users' interaction with the app, the recorded sessions were analyzed to measure the time each student took to complete each task. Finally, students were asked to fill out the SUS questionnaire to consolidate and conclude the app's evaluation.

3. Research approach and methods

This study is a DSR, which is suggested by Hevner & Chatterjee (2010) to be a legitimate research paradigm in the information systems (IS) field. This type of research attempts to find solutions to real problems by building and evaluating technology artifacts within iterative processes. These processes consist of three main cycles: relevance, rigor, and design. The relevance cycle addresses the contextual environment of the research project. The rigor cycle defines the knowledge base that will be used in the research project, such as the theory or model that will be used in building and evaluating the technology artifact. Finally, the design cycle consists of two iterative phases: build and evaluate. The three DSR cycles for the "asmeany" app are shown in Figure 1.

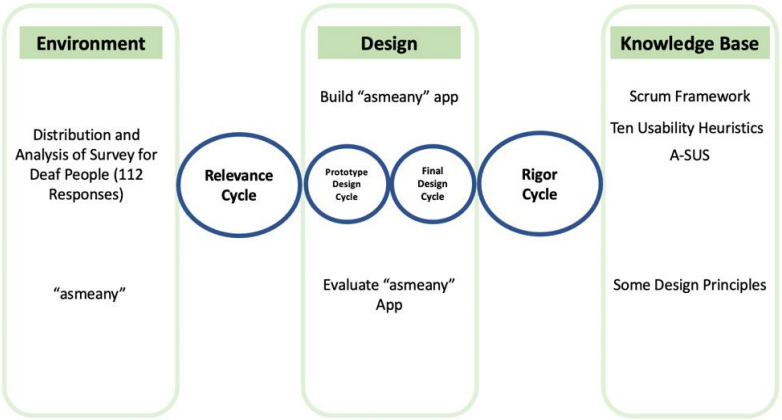

Figure 1. DSR Approach Mapped to "asmeany" App

3.1. Technology artifact: “asmeany”

The “asmeany” app is a user-friendly, intelligent Android mobile app designed to simplify the lives of people with deaf or hearing loss by providing a real-time transcript of any uploaded video (see Figure 2) using natural language processing (NLP), particularly Google’s Speech-to-Text recognition. The app supports Arabic and English. Other features of the “asmeany” app include: (1) it is free to use, (2) it allows users to copy and paste the transcript, and (3) it allows users to save the transcript.

The IT features of “asmeany” were augmented/improved after a distributed survey. We had 112 responses from deaf people from Saudi Arabia. Of the respondents, 73.2% were female and 26.8% were male, aged between 22 and 30 years old. The survey's results show that 36.6% of participants watched videos more than nine times per day. This means that viewership of videos is high, indicating that the application will be effective. Moreover, 83.8% of participants agreed that the app would be useful, which motivated us to develop the “asmeany” application. When we asked the participants about the problems that they faced while watching videos, their answers fell into two categories: (1) not all the videos were supported with subtitles/transcripts (2) there were no Arabic subtitles/transcripts. Therefore, we decided to build and evaluate the “asmeany” app with the above features.

Figure 2. The “asmeany” Home Page

Before designing the app’s prototype, we designed the system workflow to have an overview of the app’s general tasks (see Figure 3). During the prototype design cycle, we used Jacob Neilson’s ten usability heuristics to design the app’s user interfaces (Nielsen, 2020). Hence, “asmeany” has the following features:

- A progress bar when uploading a video to the server;
- Icons and words that are familiar to the users;
- Messages to allow the app access to the user device mic;
- Consistent design of all app pages and icons;
- Minimized design vulnerability to user-caused errors;
- Display of all necessary functions without user memory load;
- A bottom bar displaying all main functions for more flexibility in daily use;
- User-friendly interfaces;
- Error messages when users fill incorrect data into a registry function.

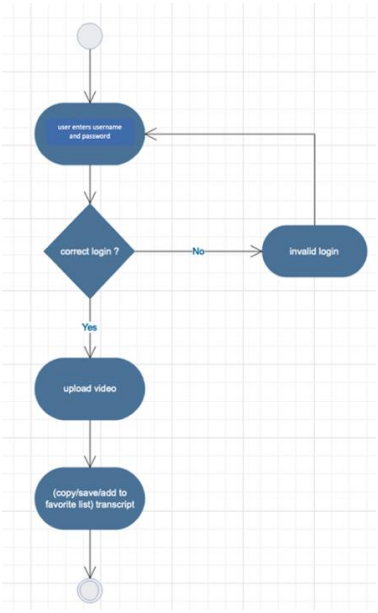

Figure 3. The "asmeany" System Workflow

We then evaluated the interfaces using A-SUS, as described in the evaluation section. Since we used the sacrum framework during the final design cycle, we developed a product backlog to list all items, including the time estimation, ordered from the highest to the lowest priority, as shown in Table 2.

Table 2. The "asmeany" Product Backlog

Priority	Requirement	Story Description	Story ID	Duration	Sprint Number
1	Register as a user	As an unauthorized user, I will be able to register to have autho-rized access to the app functions.	A	2 weeks	1
2	Log in page	As an authorized user, I will be able to enter my information to log in.	B	2 weeks	1
3	Upload video	As an authorized user, I will be able to upload video to the app to transcribe it.	C	3 weeks	2
4	Receive transcript	As an authorized user, I will be able to receive the text transcript for the video.	D	3 weeks	2
5	Copy transcript	As an authorized user, I will be able to copy the transcribed text for the video	E	1 week	3
6	Save transcript	As an authorized user, I will be able to save the transcribed text for the video into my profile	F	2 weeks	3
7	Add to favorite transcripts	As an authorized user, I will be able to add the transcript to a favorite list in my profile	G	2 weeks	3

The scrum framework is one of the most adopted agile methods that aids in simplifying the programmers' activity who break the work into small tasks to be completed within fixed timed cycles or sprints (see Figure 4). The team members must meet daily to track the progress and re-plan to develop the product (Hidalgo, 2019) incrementally.

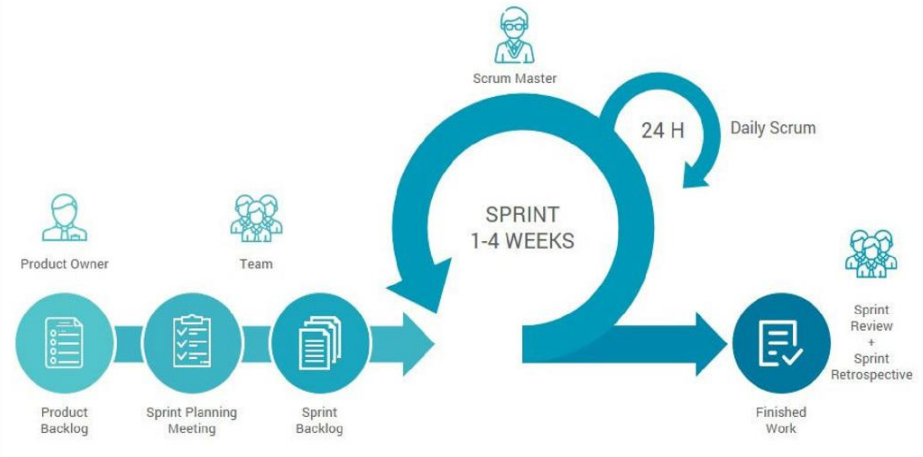

Figure 4. The Scrum Framework

Therefore, after listing all the items in "asmeany" product backlog as shown in Table 2, we started the first sprint, and after we have implemented the stories in this sprint (see Table 2), we tested and reviewed it and then moved to the next sprint. It is essential to clarify that we had a daily meeting to track the progress of the project. We followed the exact steps to develop all stories in each sprint.

Using the "asmeany" home page, users can create an account and then log in as a user. After that, users can use the app and upload any MP4 video (Figure 5). The app will provide transcripts for the uploaded videos (Figure 6). Users can also copy the transcript, paste it into favorites (Figure 7), and see all saved transcripts (Figure 8).

We developed the graphical user interface (GUI) using Android Studio, wrote the code using Java programming language and XML, and saved all user information in the Firebase cloud. We also used Google Speech-to-text recognition to write the video transcripts; however, there was an issue; even with the absence of sound in the video, the program continued recording. To solve this problem, the following rules were added: (1) when there is no sound in the video, the app will stop the recording session, and (2) once there is a sound, the app will start another recording session.

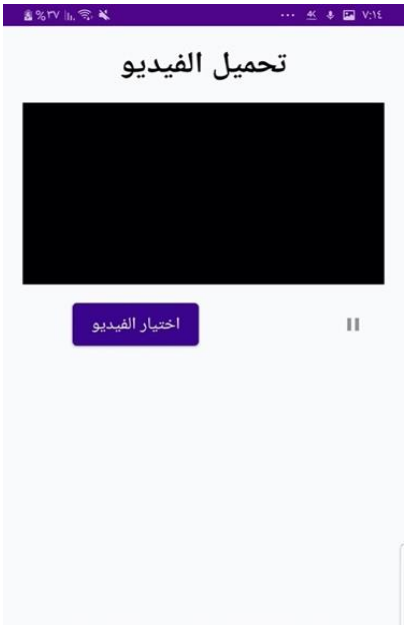

Figure 5. The "asmeany" Video Upload Page

Figure 6. The "asmeany" Transcript Page

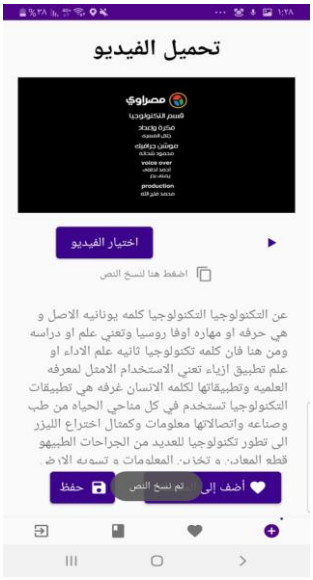

Figure 7. The "asmeany" Copy Transcript Feature

Figure 8. The "asmeany" Save Transcript Page

3.2. Evaluation

We evaluated the usability of the prototype during this study and then the utility of the final "asmeany" app from first a sociotechnical and then a technical performance perspective in two sequential stages (see Figure 9).

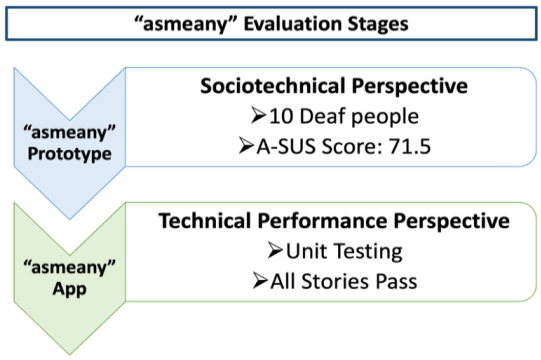

Figure 9. The Evaluation Stages of "asmeany"

In the first stage, we evaluated the usability of the prototype from a sociotechnical perspective using the A-SUS because the scale is commonly used, reliable, and freely distributed. This questionnaire has ten items and is a popular choice among professionals (Finstad, 2006; AlGhannam et al., 2018). The A-SUS also proved capable of measuring the mobile app's usability (AlGhannam et al., 2018). We recruited ten deaf participants aged 18–24 using a convenience sampling technique from King Abdulaziz University (KAU). All the participants were female Saudi students from KAU. We contacted them through KAU student affairs after getting approval from the affairs-female section, since in Saudi Arabia there is a segregation among male and female sections. The A-SUS average score was 71.5, which is considered high within the acceptable range (Brooke, 2013).

After evaluating the prototype, we evaluated the final app utility from a technical performance perspective using unit testing. According to Runeson (2006), unit testing is testing usually performed in a laboratory environment by developers to be sure that a program meets specific requirements. The developers test different units of code and then compare their actual results with the expected results. Using this method of evaluation was helpful since we used a scrum framework to develop the app. We evaluated the stories shown in Table 2. All the story cases passed the testing. Table 3 shows the unit testing results of "asmeany" app.

Table 3. "asmeany" Unit Testing Results

Test case ID	Description	Input data	Expected result	Actual result	Pass/ fail
Story A					
1	Verifies register functionnality by inserting valid values	Email: samarzaaid@gmail.com Password: 12365445	Shows confirmation message and redirects user to home page	Shows confirmation message and redirects user to home page.	Pass
2	Fails to verify register functionnality by leaving an empty field	Email: salahmdi0010@stu.kau.edu.sa Password: none	Shows an error message in the empty field.	Shows an error message in the empty field.	Pass

Story B					
1	Verifies register functionality by inserting invalid values	Email: Reemans@hotmail.com Password: 222323	Shows an error message	Shows an error message	Pass
2	Verifies register functionality by inserting valid values	Email: samarzaaid@gmail.com Password: 12365445	Shows confirmation message and redirects user to home page	Shows confirmation message and redirects user to home page	Pass
3	Verifies register functionality by leaving an empty field	Email: samarzaaid@gmail.com Password: -	Shows an error message	Shows an error message	Pass
Story C					
1	Verifies the uploading functionality by inserting valid data	The uploaded video	Shows confirmation message and uploads video to server	Shows confirmation message and uploads video to server	Pass
2	Fails to verify the uploading functionality by leaving an empty field	-	Shows an error message	Shows an error message	Pass
Story D					
1	Verifies the receive transcript function by view transcript	The uploaded video	Displays the Arabic transcript	Displays the Arabic transcript	Pass
2	Fails to verify the receive transcript by inserting invalid data	The uploaded video is in Spanish language	No transcript is displayed	No transcript is displayed	Pass
Story E					
1	Verifies copy function by inserting valid data	Click on ‘copy’	Copy transcript	Copy transcript	Pass
Story F					
1	Verifies save function by inserting valid data	Click on ‘save’	Save transcript	Save transcript	Pass
Story G					
1	Verifies add to favorite transcripts function by inserting valid data	Click on ‘favorite’	Add transcript to favorite list	Add transcript to favorite list	Pass

4. Discussion, limitation, future works, and conclusions

The utility and novelty of the application are essential to emphasize as the driving factors for this project. By providing subtitles/transcripts for any uploaded video, a significant amount of time and effort are reduced in interpreting video content. Individuals with hearing disabilities will be more involved in society since many topics are now posted and discussed in videos on different channels, such as YouTube and TikTok. This app may help solve one of the difficulties that people who are deaf or hard of hearing face daily, which is understanding the content of any video with audio information. To the best of our knowledge, the "asmeany" app is the first application built to support Arabic people with hearing disabilities by transcribing videos and providing the ability to copy and paste transcripts and save them in a favorites list. As a result of this DSR project, the following design principles are recommended when building any IT artifact for people with hearing disabilities:

1. In the methodology, use the scrum framework since it empowers user involvement through direct or indirect participation.
2. During the design:
    a. Add a customization feature where users can choose their preferred language from a dropdown menu (Arabic, English, etc.),
    b. Always add sign language as an alternative language for deaf people.

The main limitation of this study was in the evaluation phase. During the first stage in the evaluation, which is prototype evaluation, we just had female participants. In Saudi Arabia, there is gender segregation, so there are male and female sections in most universities, and KAU is one of them. Thus, including male participants during this stage may change the A-SUS average score and the evaluation results. Moreover, during the final design cycle, the project team could not evaluate the final app from a sociotechnical perspective using the app by deaf people or those with hearing loss because of the COVID-19 pandemic. Due to Covid-19 restrictions, it was challenging finding and meeting with respondents to evaluate the "asmeany" app. Therefore, this will be considered as one of the future works. Another limitation is that the app only provides a text transcript for users. At the same time, the greater benefit could be offered if the app also provided transcripts in an Arabic or English sign language, based on the uploaded video.

In future DSR cycles, the final app will be evaluated from the sociotechnical perspective by having deaf people use the actual app and rate its utility and effectiveness. The sample size for this follow-up study will be calculated via power analysis using a trusted statistical tool such as the Statistics Kingdom. Moreover, the project teams will improve the app by adding a sign language feature so that users can choose their preferred transcript outputs for the video content. Also, the app will allow the users to share the video content with others after saving the text/sign transcripts in the favorites list. The project team will be adding qualitative methods to the evaluation, for instance, semi-structured interviews of deaf people with the attendance of a translator. This would provide an in-depth understanding of their needs and ensure that the app is useful and practical for people with hearing disabilities. Some questions that could be asked during the interview are: (1) What other IT features should be added to the "asmeany" app? (2) How many times would you use this app daily? (3) What is the most useful part/feature of the "asmeany" app? These questions and others will be validated through a least construct validity test to be sure that the questions measure our intended concept. Hence, the authors will conduct a pilot test before the actual interviews, following Dikko's method (2016).

The "asmeany" app is a tool that can simplify the lives of Arabic-speaking people with hearing loss or deafness by providing transcripts of any uploaded video. This app would help these individuals to be more involved in society by understanding the video content. The "asmeany" app is easy to use and provides the transcripts of uploaded Arabic or English videos. Anyone can use this Android app to get the transcript of any uploaded video. The project teams chose the app features due to a distributed survey among Saudi Arabian people with hearing disabilities. The evaluation was performed in two stages: the prototype evaluation and the final app evaluation. The A-SUS and unit testing were used to

evaluate the useability and the utility of "asmeany", and the results were acceptable. The "asmeany" app is a promising solution to one of the difficulties affecting deaf people or hearing loss every day. Using this artifact will aid people in Saudi Arabia and around the Arab world with hearing disabilities to be more involved in society, since they will be able to understand the content of any uploaded video. More features in the app, such as transcriptions into sign language, would be useful additions to this already supportive app.

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