ASM4Deaf

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Διαρθρωτικά Ταμεία της Ευρωπαϊκής Ένωσης στην Κύπρ

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1 Executive Summary

The aim of ASM4Deaf project is to develop a cloud-based system and an innovative mobile application that will support the use of multiple sign languages within mainstream social media and networking platforms (e.g., WhatsApp, FB Messenger, Google Hangouts, Viber). More specifically, the app will integrate American Sign Language (ASL) videos/GIFs by the end of the project and envisages to add more sign languages at a later stage after the project lifetime. For this purpose, the consortium partners plan to design and develop the mobile app according to the User-Centered Design (UCD) methodology, with the aim to provide the best possible User Experience (UX) to the targeted end-users.

For the co-creation and evaluation activities that are planned to be conducted throughout the project, it is estimated that a total of 230 end-users (including primary, secondary and tertiary) will participate. As mentioned previously, a full UCD approach will be applied. To achieve this, likewise, the partners and associated partners will constantly monitor, discuss, evaluate and provide feedback based on the app design and development activities, which in turn aims to guarantee the proper implementation, integration and optimisation of the app. All these intentions are to be fulfilled using various iterative approaches, methods and tools focused on end-users in order to guarantee the usability and effectiveness of the app but also the willingness of the end-users to purchase it.

The report documents the most important aspects in terms of end-user recruitment and involvement throughout the research activities, as well as important considerations and requirements at this stage for the design and development of the mobile app. Hence, an overview of the end-user categories and their involvement in the process of the design and development of the app is presented.

2 Human-Computer Interaction

Simply stated, Human-Computer Interaction (HCI) is the field concerned with improving the design and development of websites/applications for users. The ACM SIGCHI Curricula for Human-Computer Interaction defines HCI as the following (Hewett, Baecker, Card, Carey, Gasen, Mantei, et al., 1996, p. 5):

> "HCI is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them."

The purpose of HCI is to achieve a certain level of performance in terms of the quality and optimality of a service. In order to realise this, a fit has to be produced between the user, the machine and the actual service. Determining whether an HCI design is good is largely subjective and dependent on the context (Te'eni, 2006). The human,

computer, use and context are the main characteristics in the development process. Figure 1 provides a representation of the nature of HCI (Hewett et al., 2002).

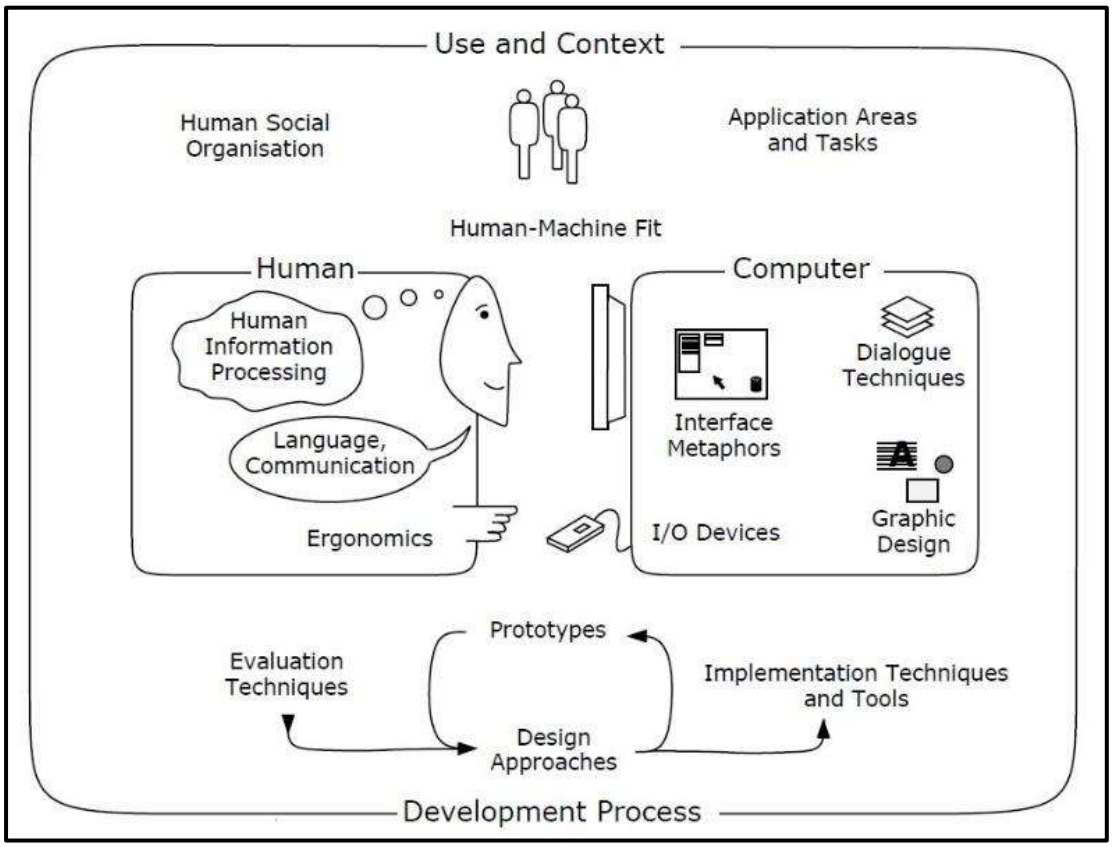


Figure 1: The nature of HCI (Hewett et al., 2002, p. 13)

In the process of HCI design, the degree of activity between the human and the computer must be well-thought through. User activity has three different levels: these include physical, affective and cognitive. Accordingly, the physical aspect focuses on the mechanics of interaction between the human and the computer; the cognitive aspect focuses on the ways in which the human can understand the system and interact with it; and the affective aspect focuses on making the interaction a pleasurable experience for the human and ensuring that the human continues using the machine. This aspect depends on emotions and attitudes (Karray, Alemzadeh, Saleh & Arab, 2008).

HCI is an extensive subject area that includes a number of terms and disciplines, as previously mentioned. These are either used interchangeably or applied to complement each another during design. Nonetheless, they all share the common goal of improving the intended users' experience by making them the focal point of the design. Some of the more familiar disciplines are UX, UCD, User Interface (UI) design, Interaction Design (ID), Information Architecture (IA) and usability. Their objectives can overlap as a result of their interdependencies.

Owing to the terms and disciplines that exist in the area, it is difficult to provide a definite consensus on their relationships. Literature indicates different views with

regard to this, yet not necessarily conflicting ones. This has become even more complicated by the surface of UX. Accordingly, extensive research has been conducted to define UX design and its role with the other disciplines. Therefore, it is appropriate to provide a stance on the perspective that is taken in this research study, as this will enhance the understanding of this chapter in terms of the disciplines discussed.

With regards to HCI, Saffer (2009) states that it has different (non-design) traditions and methodologies in comparison to the other disciplines. This is a result of its pure research focus. Based on Saffer's (2009) views and because this is a pure research project, this study is positioned within the field of HCI, even though Saffer and the ACM SIGCHI Curricula for Human-Computer Interaction refer to HCI as a discipline as well. Within HCI, this research study will investigate the disciples of UCD, usability and UX. In agreement, Saffer (2009) presents UX design as a discipline that overlaps with all other disciplines and that needs to be considered in each.

3 User-Centred Design

The purpose of UCD is to develop products with a high degree of usability. To achieve this, the user becomes the centre of focus in the product development process. Usability is therefore the outcome of correct UCD. Owing to their dependant relationship, it is worth introducing UCD before usability is discussed in section 2.4. UCD is defined as the following (Henry, 2007, p. 29):

> "UCD is a user interface design process that focuses on usability goals, user characteristics, environment, tasks, and workflow in the design of an interface. UCD follows a series of well-defined methods and techniques for analysis, design, and evaluation of mainstream hardware, software, and Web interfaces. The UCD process is an iterative process, where design and evaluation steps are built in from the first stage of projects, through implementation."

To better understand the concept on which UCD is founded, it would be beneficial to first compare it to an alternative approach that is used when developing software products, the system-centred design approach (SCD). The design of a new system in SCD is highly focused on the actual characteristics of the system. For example, designing a product that is to run on a particular platform will evidently influence its design process. This is because the new system will need to be designed in such a manner that it optimises and fits into the platform for which it is intended (Leventhal & Barnes, 2007). In UCD, however, the focus of the design is not based solely on the system characteristics, as it is in SCD. Instead, it is based on the fundamental objective to best address the users' needs and tasks. This is the vehicle that drives the design process. The needs and tasks of users must also be in line with what is stated in the requirements documents. It is even possible to sacrifice certain system

efficiency in order to address users' needs with regard to their interactions with the interface (Leventhal & Barnes, 2007).

It is evident that UCD depends on the participation of the intended users of a new product throughout the design process. Terms that are used synonymously with UCD are Human-Centred Design (HCD) and User-Centred System Design (UCSD). ISO 9241-210 (2010), however, states that, in the case of HCD, it also addresses the impact of the stakeholders and not only those of the users, as in UCD. HCD is defined as the following (ISO 9241-210, 2010, p. 2):

> "HCD is an approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques."

As with HCD, the definition for UCSD identifies the user as the focal point of the design by stressing the importance of usability throughout the design process. UCSD is defined as the following (Gulliksen, Goransson, Boivie, Blonkvist, Persson & Cajander, 2003, p. 401):

> "UCSD is a process focusing on usability throughout the entire development process and further throughout the system life cycle."

Gathering requirements from users and involving them in the design process is not a simple task. Nevertheless, there are various investigative methods that can help the design team accomplish this effectively (Benyon, Turner & Turner, 2005), some of which will be used in the ASM4Deaf project and elaborated on in the following sections.

4 Human-Centred Design Activities

As mentioned previously, the terms UCD and HCD are used interchangeably; therefore, discussing the activities involved in HCD is relevant. There are four main activities that compose the HCD approach. These are displayed in Figure 2. It is also worth noting that the HCD activities will only initiate once it has been confirmed that there is a need to design a new system, product or service. This is represented in the top circle of the figure, referred to as "Identify need for human-centred design".

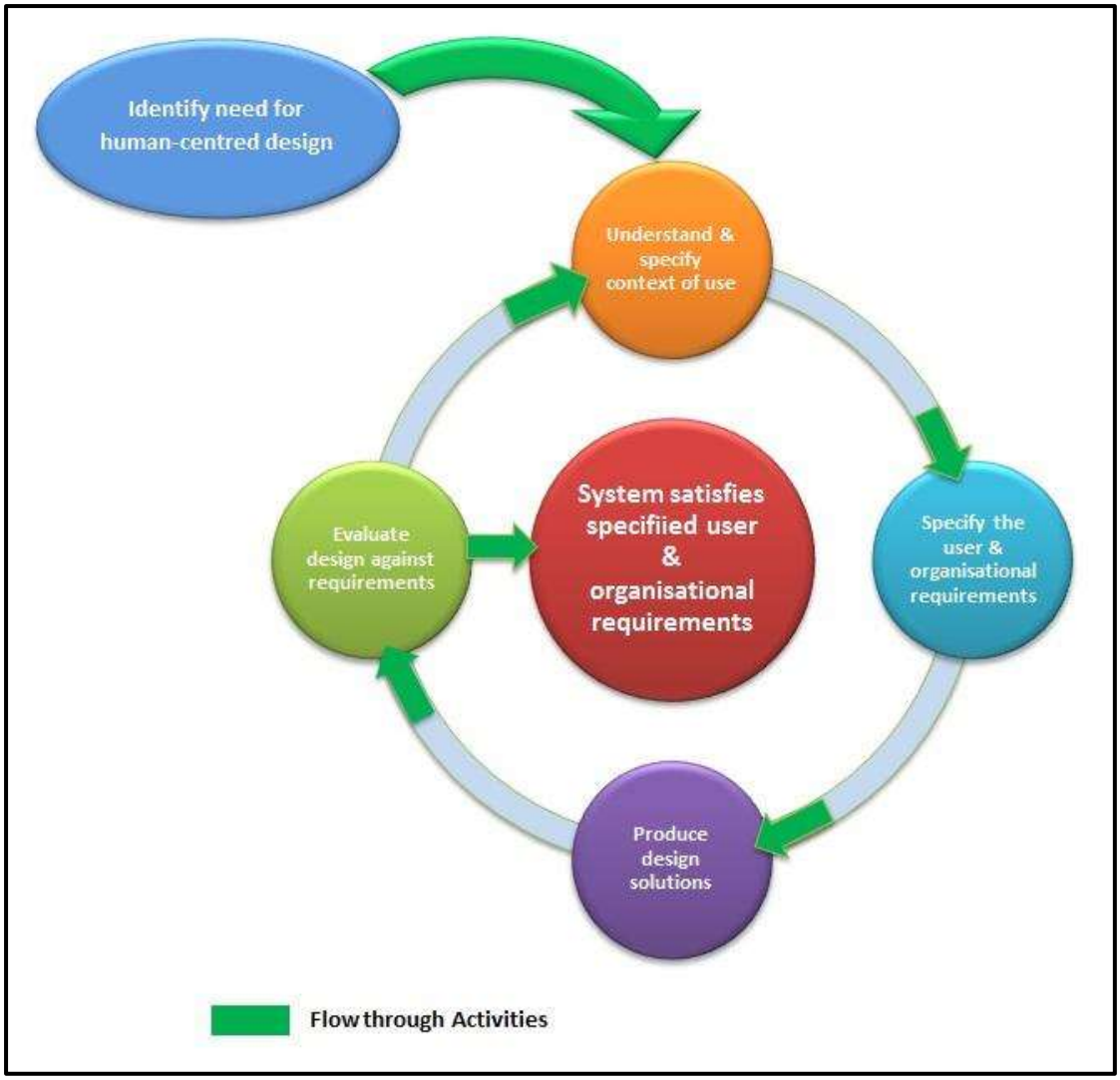


Figure 2: The interdependence of human-centred design activities (ISO 13407, 1999; ISO 9241-210, 2010)

Once the need for HCD has been established, the next step is to understand the context in which the new system will be implemented. A brief overview of this and the other activities will now be provided. The four activities are the following (ISO 13407, 1999; ISO 9241-210, 2010):

1. Understand and specify the context of use. Context of use encompasses the characteristics of the intended users, the tasks that the users will need to perform and the environment (organisational, technical and physical) in which the users will be using the system.

In this project the context of use is the mobile platform environment and the users utilise American Sign Language as a first language for their communication purposes and generally have poorer literacy skills than users that utilise a spoken language as a first language.

2. Specify the user and organisational requirements. This activity determines and specifies the major requirements of a new system, product or service. It needs to be extended by creating an explicit statement of user requirements. These requirements are dependent on the intended users, context of use and the organisational objectives.

In this project basic user requirements have been defined at the proposal stage, but based on the feedback to be collected from users and experts throughout the co-creation and evaluation activities, they will be finalised. The methods for data collection include user surveys, focus groups/workshops and prototyping.

3. Product design solutions. Potential design solutions are produced as part of this activity. The solutions are based on the description of the context of use, results from any baseline evaluations and the established state of the art in the application domain. Design and usability standards and guidelines, as well as the experience and knowledge of the multidisciplinary design team are all crucial. Iteration is essential at this point and can result in additional user requirements.

In this project, low- and high-fidelity porotypes will be designed and evaluated, hence iterations will occur between the two designs, also supporting a co-design process.

5. Evaluate designs against requirements. User-centred evaluation is essential in determining if the human-centred design process is a success. Moreover, new information regarding user requirements may be collected and baselines can be established for comparing alternative designs. User-centred evaluation can provide feedback, which can then also be used to further a preferred design and assess if user and organisational objectives have been fulfilled. Additionally, it helps monitor the long-term use of the system, product or service.

In this project, the protypes that will be designed, as described in the previous step, they will ultimately be used as tools to conduct user evaluations in order to determine whether the requirements of end-users have been satisfied.

5 Accessibility, Usability and User Experience

Individually, accessibility, usability and UX are well-established concepts for user interfaces and websites. Their relationships however are not clearly defined, resulting in alternative perspectives, especially for accessibility and usability (Yesilada et al., 2012). The ISO 9241-210 (2010) defines usability as:

"The extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use".

It defines accessibility for interactive systems as:

"Usability of a product/service by people with the widest range of capabilities"

Lastly, it defines UX as:

"A person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service".

Viewing the relationships between usability and UX, and usability and accessibility separately may provide more clarity on the definitions of ISO 9241-210 (2010).

In terms of the relationship between usability and UX, Kim (2012) describes UX as the external judgments of users on the quality of a product/service, which is influenced by their expectations, satisfaction, and experience. Usability ensures that the user interfaces are easy to use and support users in performing their tasks efficiently and effectively (Kim, 2012). Consequently, *usability is more concerned with the tasks that users must perform and their level of accomplishment*. In terms of the user and product/service relationship, it is on the pragmatic side (Hassenzahl & Tractinsky, 2006). UX aims to find a balance between the pragmatic and hedonic (e.g., beauty, stimulation, challenge and self-expression) aspects of product/service use and possession, hence having a more holistic approach.

In terms of the relationship between usability and accessibility, Yesilada et al. (2012) mention that there is no clear understanding even though some insights have been presented in research. They highlight several different views on this relationship. The first view is that problems for accessibility and usability are distinct, meaning that problems experienced by people with disabilities and people without are different. The second view is that accessibility problems are a subset of usability problems and the third view is that "universal usability" encompasses both usability and accessibility problems. This infers that the scope of usability is broadened to address problems disabled people experience too. The fact that there is no common understanding on accessibility makes it even more difficult to define this relationship (Yesilada et al., 2012). In an attempt to harmonise an understanding of accessibility via the comparison of different definitions, Yesilada et al. (2012) conclude that web accessibility means that people with disabilities can use the web. This entails that people with disabilities can perceive, understand, navigate and interact with the Web, and also contribute to it (Henry, 2006).

Petrie and Kheir (2007) believe that the ultimate criteria for accessibility should be user-based. Considering the definition of usability, as defined in ISO 9241-210 (2010), an adapted definition of accessibility is proposed. It is defined as "the extent to which a product/website can be used by specified users with specified disabilities to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (Petrie & Kheir, 2007). Accessibility and usability problems are seen as two overlapping sets, which include three categories: "pure accessibility" problems that only affect disabled people, "pure usability" problems that only affect non-disabled people and "universal usability" problems that affect both disabled and non-

disabled people (Petrie & Kheir, 2007). Similar views were expressed by Yesilada et al. (2012), as previously mentioned.

As a point of departure for the ASM4Deaf project, usability and accessibly problems are seen as a set of overlapping problems that fit into the category of "universal usability" problems. In our understanding, "pure usability" problems can affect disabled and non-disabled people and "pure accessibility" problems will affect disabled people more. Both these sets of problems can affect the balance between the pragmatic and hedonic aspects of the mobile app use and possession. Hence, it is deemed important to consider guidelines that address accessibility and usability problems in the mobile app design and development because they will both influence the experience of the primary end-user, i.e., user who is deaf and uses ASL predominantly, but also the secondary and tertiary end-users experience. To address these problems a set of structured instruments will be considered for use, which are presented in Appendix 3.

6 Usability Inspection Methods

"Would you fly in an airplane that hasn't been flight tested? Of course not. So you shouldn't be using software that hasn't been usability tested" (Shneiderman, 1995).

Usability Inspection Methods (UIMs) are used to evaluate the usability of applications/websites in the field of HCI. This is achieved by identifying usability problems or violations using an interface. A usability problem is defined as "any aspect of a user interface that is expected (or observed) to cause users problems with respect to some salient usability measure (e.g., learnability, performance, error rate, subjective satisfaction) and that can be attributed to a single design aspect" (Nielsen, 1993). Once usability problems have been identified, they can be prioritised for improvement according to their severity. Hence, it is imperative that one can trust the validity of the ratings from the applied UIM. Otherwise, less urgent usability problems may be addressed ahead of the more severe and urgent ones (Law & Hvannberg, 2004).

Other terms used interchangeably with UIMs are discount methods (Woolrych & Cockton, 2001), usability evaluation methods/techniques (Dix, Finlay, Abowd & Beale, 2004) or usability evaluation approaches/methods (Rogers et al., 2008). The term discount methods are used because their main goal is to provide the best possible impact on interactive design at the lowest possible cost (Woolrych & Cockton, 2001). According to Dix et al., (2004) usability evaluation methods/techniques are either based on expert evaluation or user involvement. Likewise, the three types of usability evaluation approaches/methods include usability testing, field studies and analytical evaluation (Rogers et al., 2008). Usability testing measures users' performance and satisfaction when conducting tasks in a laboratory setting on a system in question. Field studies are conducted in natural settings to understand what users do naturally

with a system in question, while analytical evaluations are conducted by experts and do not involve users. Thus, the selection of a particular method to be used is mainly founded on determining whether it will be conducted with experts or users.

Despite the high cost involved with using both users and experts in evaluations, it is beneficial. The continuous involvement of users in the design and evaluation phases must reflect the application of usability practices throughout in order to meet their needs (BoK-a, 2005). In addition to user involvement, expert involvement will complement and enhance the design process. Thus, the user requirements will be combined with business requirements in order to achieve effective UX (BoK-b, 2005). UIMs are particularly fundamental for data collection and analysis within the HCI research field.

When conducting evaluations with users, it is recommended to have at least three to five users for a single user group. If there are more user groups identified, the development team will need to ensure that each user group is represented with three to five users. Context is another important consideration with users – it will need to be recreated so that it matches the actual settings in which users are expected to interact with the product (e.g., usability laboratory). On the other hand, when conducting evaluations with experts, results are dependent on their personal experience, practical and theoretical knowledge. These evaluations require a considerable amount of time and close attention to detail in the design. Overall, the best results are obtained when conducting evaluations with both users and experts, as the methods will complement each other.

Once the data have been collected, the design and development team can employ methods and models for the analysis. These are also helpful in communicating the requirements to the team. Such examples include flow models, sequence models, artefact models, cultural models, physical models, affinity diagrams, storyboards, User Environment Design (UED), paper prototypes, and Graphical Presentation of User Profile (GUP) (Benyon et al., 2005; Kankainen & Parkkinen, 2001).

When conducting evaluations with users, it is critical that the evaluators observe, listen and engage with the users effectively. Richer results are obtained when the onsite visits are done at users' natural environments. Alternatively, the context can be recreated in usability laboratories as well (Butow, 2007). Drawbacks can include bias from the evaluators due to the lack of adequate feedback from the users or a general lack of information from them and misunderstandings. These drawbacks result when there is confusion and when users' actions are interpreted incorrectly.

Table 1 displays some of the more commonly used UIMs that are conducted with users, experts or both. It also displays those that will be applied in the research for the ASM4Deaf project. The UIMs to be applied to evaluate the ASM4Deaf mobile app are briefly discussed next.

	UIM	Users	Experts	Users & experts	Applied in ASM4Deaf
1	Usability roundtable	√			
2	Usability evaluation	√			
3	Focus group			√	√
4	User survey	√			√
5	Cognitive walkthrough		√		
6	Action analysis		√		
7	Claims analysis		√		
8	Contextual inquiry	√			
9	Heuristic evaluations			√	
10	Prototyping	√			√

Table 1: Commonly used UIMs and the selected ones for ASM4Deaf

6.1 Focus Group

Focus groups help obtain attitudes, reactions and opinions about a product and ideas. They are also useful for helping in better understanding user requirements (Butow, 2007). A focus group is an informal technique that assesses user needs and feelings before interface design and after implementation. Nielsen (1997) suggests that it is more effective when the group consists of six to nine users and the session last for about two hours. The session will also need to be administered by a moderator, who maintains the focus of interests. However, there still needs to be a free-flowing and relatively unstructured style to the session.

Focus groups in particular cannot be used as the only evaluation method and are relatively poor in evaluating user interface usability. They can also possibly produce inaccurate data, as users may think that they require one thing when instead they require another. One will need to consider a solution for this (e.g., using them in parallel with prototypes, workshops and scenarios) (Benyon et al., 2005). Note that the main purpose of focus groups is not to assess the usability of the design but to discover what it is that the users need from the product.

6.2 User Survey

User surveys (i.e., interviews and questionnaires) help determine what the users would like to see in the product or what do they think about the product. These are valuable for clarifying user reactions and perceptions. Information collected from the user surveys can also be applied to future versions of a product (Butow, 2007).

Essentially, a sample group of participants will be selected and a standardised survey will be administered to each of them (Babbie, 2005).

6.3 Prototyping

Prototypes, a draft version of a product, offer one the opportunity to explore ideas and show intentions with regards to features and design in a time and cost-effective manner. Prototypes have various degree of detail, ranging from paper drawings (low-fidelity) to more interactive designs (high-fidelity), which enable one to interact with some content or functionality. Their significant value comes from the fact they can save on development costs and time by introducing them early on and throughout the design and development process since it is cheaper to make changes before any code has been written rather than when implementation has commenced or completed. Most importantly, they are a source from which valuable feedback can be collected from users in order to improve a product. It has been shown that the biggest improvements in UX arise from gathering usability data as early as possible.

Prototyping helps in identifying usability issues. Even though paper-based low-fidelity prototypes do not allow for user interactions, they help in identifying possible technical and design limitations from the onset. They are used to demonstrate the early visualisation of the design, which in turn helps provoke innovation and improvement. It should be noted that during Lo-Fi prototyping, in addition to improving the design through a HCD approach, its likewise an opportunity to explore one's imagination and thoughts about the design. It is an ideation phase that has no restrictions. As such, our aim will also be to explore a number of ideas, some of which, might be more complicated to actually implement from the onset. It will serve as an opportunity for the consortium though to therefore collect feedback on some of these ideas that could possibly be implemented in future implementations too, if so, the appropriate desire was expressed by the users for them.

High-fidelity protypes are interactive prototypes that allow for user interactions, unlike the low-fidelity (Lo-Fi) protype. Such prototypes look and work very similarly as to how the app should, once its finally developed. In short, Hi-Fi prototypes are computer/mobile-based, and support realistic (mouse-keyboard-tapping) user interactions. Moreover, they offer one a close as possible to a true representation of the user interface design. Equally importantly, they are deemed more effective in collecting true human performance data (e.g., time to complete a task), and in demonstrating actual products to users, clients, management, and others.

7 Definition of End-Users

In this section, a detailed description of the end users is provided, also presenting the related information about the evaluation process of the ASM4Deaf project.

7.1 End-user categories

The consortium defined three main categories of end-users in the ASM4Deaf project. Table 2 introduces in the terms of primary, secondary and tertiary end-user. A fourth category that is identified is "Other end-user".

Primary end-user	Individuals who are deaf and use sign language as a first language. They would also be owners of a smartphone and be users of mainstream social media and networking apps. The solution to be provided aims to offer these users a new and improved user experience within these environments, making them more inclusive to the needs of the primary users.
Secondary end-user	Individuals who are not deaf but are in direct contact with primary users. This group includes family members, friends and colleagues. Deaf associations and schools also fit in this group.
Tertiary end-user	Group of public or private organizations that are in direct contact with the primary users. This includes institutions in the public sector (especially in the field of health, social affairs and transport) and the private sector, including mobile telecommunication companies (e.g., AT&T, Verizon, Vodafone, Cyta etc.).
Other end-user	Individuals who are not deaf, do not know sign language and do not have direct contact with the primary users. However, they are interested in learning sign language and find the proposed solution as an engaging and fun way to learn and use in their mainstream social media and networking apps.

Table 2: End-user categories in the ASM4Deaf project

7.2 End-user involvement

A phased approach towards end-user involvement will be adopted during the project lifetime. To this extent, a "base-line" of methods that constitute the phased approach have been defined by the ASM4Deaf team. There are three main phases, all of which are composed of several methods and approaches. These are the following:

1. Initial investigations
2. Co-creation approaches
3. Evaluations

Initial investigations are conducted in the first phase to ensure that the idea of the how the mobile app should function and look are first technically possible and inline with budget restrictions. Secondly, with the involvement of AnnRae Consulting, LLC, who is a voice for the community of the Deaf, these discussions will also focus on whether the initial design ideas, are close enough to the aspirations of the primary end-users.

In the next phase of end-user involvement, more co-creative methods are applied, which rely heavily on stimulating interaction with the categories of end-users and the creativity that can approached. This is in the form of workshops and focus group sessions.

In the third and final phase, more structured approaches appear in order to evaluate the mobile app designs and collect feedback mainly from primary- and secondary-users. Instruments are vital for this purpose, which also act as "design guidelines" to the design and development teams. The expectation is that by knowing what the test apparatus will include, these aspects will be also put in place in the mobile app. Development and evaluation of the mobile app for the ASM4Deaf mobile app will be based on the application of some of the following structured instruments and guidelines, which are also presented in Appendix 3:

- User Experience Questionnaire (UEQ)
- System Usability Scale (SUS)
- Usability Heuristics for User Interface Design
- Universal Design
- Web Content Accessibility Guidelines (WCAG) 2.0
- HCI checklist for designers, developers and test leaders.

In addition to the structured instruments, an observation sheet may be useful to record any other aspect of end-user behaviour, questions, comments or the like. In particular, if end users do not approve video recording or it is not possible or appropriate to do, an observations sheet provides good support. An observation sheet template is drafted in Appendix 2.

It should also be noted that at this stage of the project, the aforementioned, are preliminary selection of tools and methods based on which the final set of evaluation tools and instruments will be defined along the project duration in the respective tasks.

As highlighted in section 7.1, the different categories of end-users that are to be recruited in the co-creation activities of the ASM4Deaf project, are as follows:

- Primary end-users: persons who are deaf and use sign language as a first language (i.e., ASL and CSL).
- Secondary end-users: Family members, friends, colleagues of primary end-users and associations and schools for deaf persons.

- Tertiary end-users: Private and public organisations and stakeholders (mobile telecommunication vendors, policymakers, social affair services, healthcare professionals etc.).

The number of end users to participate in the project from the different categories can be extracted from the proposal. In the different phases of the project, the target numbers/aim have altered due to COVID19 and are presented in Table 3.

Primary end-user	The test person him/herself, who is willing to evaluate the prototypes of the mobile app.	Ten primary users in the US (i.e. ASL users) will evaluate the low- and high-fidelity prototypes	AnnRae Consulting, LLC will assist A.G. Connect Deaf Limited in conducting and collecting the results from the evaluations.
	Two workshops will be held to perform a survey on personal experiences of deaf adults in Cyprus and perform a wider testing to receive valuable feedback on the mobile app prototypes. Most will be primary users.	Over the two workshops the aim will be to collect feedback from 20 users in total. From this total, 10 will be primary users.	A.G. Connect Deaf Limited will assist UCY and FRC in collecting the data for the surveys.
Secondary end-user	Feedback will be collected from secondary end-users as well during the two workshops, i.e., sign language interpreters, family, friends, teachers at the school of the Deaf in Cyprus.	Over the two workshops the aim will be to collect feedback from 40 users in total. From this total, 20 will be secondary users.	A.G. Connect Deaf Limited will assist UCY and FRC in collecting the data for the surveys.

Tertiary end-user	Feedback will also be collected from private and public institutions.	Two innovation days will be organized. One will be a physical event in Cyprus (FRC and/or UCY facilities) and the second an online event with international audiences from Europe, to raise awareness, increase mobile application adoption and promote the project activities and results. The diverse participants will include potential customers, partners, investors, companies, local and European communities, public, government institutions, and policy makers. They may also receive an online link to a questionnaire with the request to fill it out online. Over the two workshops the aim will be to collect feedback from 20 users.	A.G. Connect Deaf Limited will assist UCY and FRC in collecting the data for the surveys.

Table 3: The approach towards end-user involvement during the project

From the beginning of the project and then as soon as the prototypes are ready, GrantXpert will start promoting the project via social media channels (such as Facebook, Instagram and LinkdIn) and over the project website. English will be the main language of communication, yet the website will also have a Greek version.

Since AnnRae Consulting, LLC already interacts with people who are deaf in the US, information will be communicated to them directly. Regarding the deaf community in Cyprus, A.G. Connect Deaf Limited, UCY and FRC will contact the school of the deaf in

Nicosia in order to communicate the project to them and have them also participate in the ASM4Deaf project.

The following procedure has been considered for recruiting the test persons:

- Ten primary users in the US (i.e., ASL users) will evaluate the low-fidelity and high-fidelity prototypes. AnnRae Consulting, LLC will be responsible to recruit these participants through their extensive network within the deaf community in the US. Prototypes will be presented and participants are given the opportunity to share their feedback but also ask questions about the proposed solution.

- Twenty primary and secondary users who will participate in two local workshops in Cyprus will also provide feedback. A.G. Connect Deaf Limited, UCY and FRC will contact the school of the deaf in Nicosia to organise the two workshops and the school will assist with recruiting more participants, in addition to their own students, teachers and sign language interpreters. Prototypes will be presented and participants are given the opportunity to share their feedback but also ask questions about the proposed solution.

- Twenty tertiary users who will participate in two innovation days that are to be organized by GrantXpert. One will be a physical event in Cyprus and the second an online event with international audiences from across Europe. The aim will be to raise awareness, increase mobile application adoption and promote the project activities and results. Moreover, to promote the mobile app to private and public entities, as well as deaf associations.

In all the data collection activities, users will receive detailed information about the project and participants, as well as a template of informed consent form in English and Greek for local events. A template of the English version is presented in Appendix 1.

7.3 Inclusion and exclusion criteria of users

Criteria have been determined relating to the sample of users who will be recruited to participate in the evaluation activities of the ASM4Deaf project. These are presented below.

Inclusion Criteria:

- Teenage participants aged 15-18
- Adult participants aged 18 and over
- American Sign Language users
- Cypriot Sign Language users

- Owners of an iOS or Android smartphone
- Users of mainstream social media and networking apps (e.g. Telegram, WhatsApp, FB messenger, Google Hangouts etc.)
- Diversity in subjects in terms of ethnicity and gender
- Signed consent
- Relatives/friends/colleagues who are not ASL/CSL users

Exclusion Criteria:

- Deafblind persons
- No voluntariness
- No consent of the participant

It should also be noted that signers will also be recruited to record the videos/GIFs. A flyer will be created to receive applications from those who are interested. Vaccinated participants will be eligible and the aim will be to recruit a maximum of seven signers. To enhance the diversity of signers, a BIPOC inclusive approach will be pursued.

7.4 Management of drop-outs

Aiming for a low drop-out rate in end-user involvement activities, the Key Performance Indicators (KPIs) are set at

- Maximum 10% of primary users drop off from using the ASM4Deaf prototypes.
- Maximum 20% of secondary- and tertiary-users drop off from participating in the two workshops and two innovation days.

Participants can be the same across the different phases of the project. The project partners will also counteract the negative effect of end-users dropping out by recruiting larger pool of end-users than needed. To gain this, the partners throughout the project, will lean on a number of different recruitment techniques. These are mainly the following:

- utilising the ASM4Deaf researchers' personal contacts from professional and previous project contexts
- contacting associations for the Deaf and NGOs in the U.S, Cyprus and EU
- announcing on the ASM4Deaf project's and the project partners' Facebook pages, combined with promoting the posts
- announcing on project's and project partners' websites.

Lastly, it should be pointed out that due to the COVID-19 pandemic, end-user involvement may be affected and thus online activities may be required. National rules will apply at all times.

8 Baseline App Requirements and Considerations

The proposal of ASM4Deaf project mentions specific requirements for the mobile app. These are considered as baseline requirements and through the various evaluation activities that are to be conducted throughout the project, requirements may be updated to an extent. Moreover, technical restrictions may also impact decisions with regards to the final set of requirements. Table 4 lists the baseline requirements at this point of the project.

Requirements	
Sign language	American Sign Language
Recorded words	1000
Recorded phrases	100
Facial expressions	50
Interpreters in recordings	Diversity in terms of ethnicity and gender of the interpreters who will be recorded
2D SLA (fingerspelling) keyboards	Design and develop four new SLA keyboards: Russia, Canada, Mexico and Italy.
Themes	5 new themes to be designed for the existing Connect Deaf app
2D left-handed SLA keyboards	The existing Connect Deaf app only offers right-handed keyboards for SLAs that use one hand. Left-handed keyboards will be created for 9 SLAs: Cyprus, Greece, South Africa, America, Brazil, China, Germany, Ireland and France.
3D SLA keyboard	A 3D ASL keyboard will be designed and developed.

Table 4: The app's baseline requirements as presented in the ASM4Deaf proposal

The initial idea in terms of how the app would function is presented in Table 5. The consortium envisages it as a 3-step process for end-users, in which they select a torso, followed by a selection of the facial expression (to pair with the torso) and then posting the outcome.

Step 1	

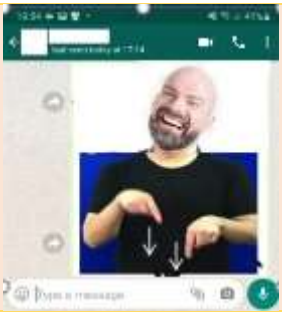
Step 2	
Make the pairing	
Step 3	

Table 5: The app's 3-step process of use

There are several critical considerations for the app that will require further investigation by the consortium. These are pointed out in Table 6.

Considerations	
Recording format	Determine whether recordings will be videos or GIFs
New or existing app	Determine whether a new app will be designed and developed or whether the existing Connect Deaf app will be upgraded with the proposed functionality.
Translations	Determine whether translations could be done between text and ASL
Processing approach	Determine whether pre-processing (i.e., storing all combinations of the torso + facial expressions in the database or ii) real-time processing will be implemented.
Matching approach	Determine which recordings will be using the approach of cropped torso and facial expressions matching individually or as a combination.
Recording background	Determine whether recordings will have backgrounds as greenscreen (green/raw) or as keyed (black).

Database	Determine the type of metadata to be stored that will enable querying the database and getting the most appropriate results.
Video editing	Determine whether the recordings can be edited by the user.

Table 6: Technical considerations for the development of the app

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Appendix 1: Consent form for primary end-users – English version

ASM4Deaf logo (funding body and participants)

Consent form: ASM4Deaf

The ASM4Deaf app is … The ASM4Deaf project is financed by …

This project is about finding out how the ASM4Deaf app works for you.

Please tick the box below if you agree:

- ❑ I have received understandable information about the ASM4Deaf project and the purpose of my participation in the ASM4Deaf project
- ❑ I participate voluntarily in the ASM4Deaf project
- ❑ I understand that I may, at any time, drop out of the ASM4Deaf project
- ❑ I understand that if I drop out of the project, I do not have to express any reason for my decision

Please put ticks in the boxes below if you are happy to:

- ❑ Use the ASM4Deaf prototypes in test settings
- ❑ Use the ASM4Deaf prototypes at your home
- ❑ Talk to us about yourself and your experiences of using the ASM4Deaf prototypes
- ❑ Allow us to use structured and semi-structures questionnaires to register your usage of the ASM4Deaf prototypes and your opinions of it
- ❑ Allow us to take photographs of you using the ASM4Deaf prototypes

Please put ticks in the boxes below if you are happy for anonymous non-confidential information you tell us about you, and what you tell us about your experience with the ASM4Deaf prototypes, along with photographs, to be used in:

- ❑ reports

- ❑ at conferences
- ❑ on the web

If you are not happy with any of the points above – please tell us now.

Your name: _____

Your address: _____

Your signature: _____

Today's date: _____

We will not use your whole name or address in any of our publicity. We request these details only for our records.

Signature of primary user: _____

Photo(s) of the researcher(s)

For more information speak to XXX

Contact details:

Appendix 2: Observation sheet

Observation sheet

Mobile app for ASM4Deaf project

Country:	Date:
Name or code of informant:	

Observations:

Appendix 3: Structured instruments

User Experience Questionnaire (UEQ)

	1	2	3	4	5	6	7	
annoying	○	○	○	○	○	○	○	enjoyable
not understandable	○	○	○	○	○	○	○	understandable
creative	○	○	○	○	○	○	○	dull
easy to learn	○	○	○	○	○	○	○	difficult to learn
valuable	○	○	○	○	○	○	○	inferior
boring	○	○	○	○	○	○	○	exciting
not interesting	○	○	○	○	○	○	○	interesting
unpredictable	○	○	○	○	○	○	○	predictable
fast	○	○	○	○	○	○	○	slow
inventive	○	○	○	○	○	○	○	conventional
obstructive	○	○	○	○	○	○	○	supportive
good	○	○	○	○	○	○	○	bad
complicated	○	○	○	○	○	○	○	easy
unlikable	○	○	○	○	○	○	○	pleasing
usual	○	○	○	○	○	○	○	leading edge
unpleasant	○	○	○	○	○	○	○	pleasant
secure	○	○	○	○	○	○	○	not secure
motivating	○	○	○	○	○	○	○	demotivating
meets expectations	○	○	○	○	○	○	○	does not meet expectations
inefficient	○	○	○	○	○	○	○	efficient
clear	○	○	○	○	○	○	○	confusing
impractical	○	○	○	○	○	○	○	practical
organized	○	○	○	○	○	○	○	cluttered
attractive	○	○	○	○	○	○	○	unattractive
friendly	○	○	○	○	○	○	○	unfriendly

conservative	○ ○ ○ ○ ○ ○ ○	innovative

System Usability Scale (SUS)

	Strongly disagree				Strongly agree
	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5

1. I think that I would like to use this app frequently
2. I found the app unnecessarily complex
3. I thought the app was easy to use
4. I think that I would need the support of a technical person to be able to use this app
5. I found the various functions in this app were well integrated
6. I thought there was too much inconsistency in this app
7. I would imagine that most people would learn to use this app very quickly
8. I found the app very cumbersome to use
9. I felt very confident using the app

10. I needed to learn a lot of things before I could get going with this app

Usability Heuristics for User Interface Design (Jakob Nielsen's 10 general principles for interaction design.

1. Visibility of system status

The app should always keep users informed about what is going on, through appropriate feedback within reasonable time.

2. Match between system and the real world

The app should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

3. User control and freedom

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

4. Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

5. Error prevention

Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

6. Recognition rather than recall

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

7. Flexibility and efficiency of use

Accelerators — unseen by the novice user — may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

8. Aesthetic and minimalist design

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

9. Help users recognise, diagnose, and recover from errors

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

10. Help and documentation

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Web Content Accessibility Guidelines (WCAG) 2.0

Full reference on https://www.w3.org/TR/WCAG20/#guidelines

Principle 1: Perceivable - Information and user interface components must be presentable to users in ways they can perceive.

Guideline 1.1 Text alternatives: Provide text alternatives for any non-text content so that it can be changed into other forms people need, such as large print, braille, speech, symbols or simpler language.

Guideline 1.2 Time-based media: Provide alternatives for time-based media.

Guideline 1.3 Adaptable: Create content that can be presented in different ways (for example simpler layout) without losing information or structure.

Guideline 1.4 Distinguishable: Make it easier for users to see and hear content including separating foreground from background.

Principle 2: Operable - User interface components and navigation must be operable.

Guideline 2.1 Keyboard accessible: Make all functionality available from a keyboard.

Guideline 2.2 Enough time: Provide users enough time to read and use content.

Guideline 2.3 Seizures: Do not design content in a way that is known to cause seizures.

Guideline 2.4 Navigable: Provide ways to help users navigate, find content, and determine where they are.

Principle 3: Understandable - Information and the operation of user interface must be understandable.

Guideline 3.1 Readable: Make text content readable and understandable.

Guideline 3.2 Predictable: Make web pages appear and operate in predictable ways.

Guideline 3.3 Input assistance: Help users avoid and correct mistakes.

Principle 4: Robust - Content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies.

Guideline 4.1 Compatible: Maximize compatibility with current and future user agents, including assistive technologies.

Design for All (DfA)

Design for All is the intervention into environments, products and services which aims to ensure that anyone, including future generations, regardless of age, gender, capacities or cultural background, can participate in social, economic, cultural and leisure activities with equal opportunities.

Design for All/Universal Design should be implemented in all areas because the human beings are diverse and everyone has the wish, the need and the right of being independent and choosing the own life style without facing physical and social barriers.

Design for All criteria:

- Respectful: it should respect the diversity of users. Nobody should feel marginalised and everybody should be able to access it.
- Safe: it should be free of risks to all users. This means that all elements forming part of an environment have to be designed with safety in mind.
- Healthy: it should not constitute a health risk or cause problems to those who suffer from certain illnesses or allergies. In addition, it should promote healthy use of spaces and products.
- Functional: it should be designed in such a way that it can carry out the function for which it was intended without any problems or difficulties.
- Comprehensible: all users should be able to orient themselves without difficulty within a given space, and therefore the following are essential:
    - Clear information: use of icons that are common to different countries, avoiding the use of words or abbreviations from the local language which may lead to confusion.
    - Spatial distribution: this should be coherent and functional, avoiding disorientation and confusion.

- Sustainable: misuse of natural resources should be avoided to guarantee that future generations will have the same opportunities as us to preserve the planet.
- Affordable: anyone should have the opportunity to enjoy what is provided.
- Appealing: the result should be emotional and socially acceptable but always bearing in mind the seven precedent criteria.

Strategies to develop a product or service for All

Design for All not always allows solving all needs with a single solution that fits everyone. One of these seven strategies should be chosen:

1. To Everyone
   A single solution suitable for all potential users.
2. Adjustable

   A single product that meets the different dimensional or functional requirement of people by means of devices or mechanisms.

3. Products or services range

   A range of products and services among which the person choose the one best fits.

4. Compatible with commonly used accessories

   Adaptations or not marginalizing alternative solutions can be provided to guarantee the compatibility with accessories that a person must wear or use.

5. Premises/Product & complementary service

   Not always it will be possible to meet the needs of users only via a product, a complementary service will then be necessary.

6. Use an alternative solution to the mainly used offering similar benefits

   Sometimes the characteristics of some individuals prevent them from using products or services in the usual way. A non-discriminating alternative offering equivalent results is then advisable.

7. Customised product or service

   As is the case for most services provided by liberal professionals such as doctors or lawyers.

Universal Design (UD)

Universal Design is the design and composition of an environment so that it can be accessed, understood and used to the greatest extent possible by all people, regardless of their age, size or disability. This includes public places in the built environment such as buildings, streets or spaces that the public have access to; products and services provided in those places; and systems that are available including information and communications technology (ICT).

The 7 Principles of Universal Design were developed in 1997 by a working group of architects, product designers, engineers and environmental design researchers in North Carolina State University:

Principle 1: Equitable Use

The design is useful and marketable to people with diverse abilities.

Guidelines:

1a. Provide the same means of use for all users: identical whenever possible; equivalent when not.

1b. Avoid segregating or stigmatizing any users.

1c. Provisions for privacy, security, and safety should be equally available to all users.

1d. Make the design appealing to all users.

Principle 2: Flexibility in Use

The design accommodates a wide range of individual preferences and abilities.

Guidelines:

2a. Provide choice in methods of use.

2b. Accommodate right- or left-handed access and use.

2c. Facilitate the user's accuracy and precision.

2d. Provide adaptability to the user's pace.

Principle 3: Simple and Intuitive Use

Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.

Guidelines:

3a. Eliminate unnecessary complexity.

3b. Be consistent with user expectations and intuition.

3c. Accommodate a wide range of literacy and language skills.

3d. Arrange information consistent with its importance.

3e. Provide effective prompting and feedback during and after task completion.

Principle 4: Perceptible Information

The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

Guidelines:

4a. Use different modes (pictorial, verbal, tactile) for redundant presentation of essential information.

4b. Provide adequate contrast between essential information and its surroundings.

4c. Maximize "legibility" of essential information.

4d. Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions).

4e. Provide compatibility with a variety of techniques or devices used by people with sensory limitations.

Principle 5: Tolerance for Error

The design minimizes hazards and the adverse consequences of accidental or unintended actions.

Guidelines:

5a. Arrange elements to minimize hazards and errors: most used elements, most accessible; hazardous elements eliminated, isolated, or shielded.

5b. Provide warnings of hazards and errors.

5c. Provide fail safe features.

5d. Discourage unconscious action in tasks that require vigilance.

Principle 6: Low Physical Effort

The design can be used efficiently and comfortably and with a minimum of fatigue.

Guidelines:

6a. Allow user to maintain a neutral body position.

6b. Use reasonable operating forces.

6c. Minimize repetitive actions.

6d. Minimize sustained physical effort.

Principle 7: Size and Space for Approach and Use

Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

Guidelines:

7a. Provide a clear line of sight to important elements for any seated or standing user.

7b. Make reach to all components comfortable for any seated or standing user.

7c. Accommodate variations in hand and grip size.

7d. Provide adequate space for the use of assistive devices or personal assistance.

HCI checklist for designers, developers and test leaders

This checklist is designed to clean the interfaces to minimalistic and functional design *before* end user testing. It should be performed for all parts of the mobile app. Checklist items that are applicable to the mobile context should be applied as some of these are web-focused. Also since some of the checklist items are feature-dependant, again those that applicable at this point of the app should be applied.

PART A: Texts and fonts

- No red against green, or the other way around.
- Screen font implemented everywhere (Calibri, Arial, Helvetica or similar; no Times or similar).
- No all-caps words, and no ordinary words with a single capitalised letter *unless* grammatically correct in each language (use in button, names of persons, weekdays, cities etc.)
- Left-adjusted text (except in buttons and the like).
- No abbreviations, at least without explanation.
- Easy-to-read "normal" everyday language. Short telegram-style sentences. No "techie phrases" in error messages or guidance.

Part B: Contrast

- High contrasts between text and background everywhere (texts, buttons etc.)
- No (blurry) pictures as text background.

Part C: Navigation

- Short help texts to guide the user's next action – what to do here/next.
- Same main basic action buttons in all service (Start, Quit, Exit, Save, Home, Back, Reload, etc.)
- Same button colours and button formats across the screens.
- Always a short way "home", possible to go "back" and exit without any disaster.

Part D: Design

- Simple colour scheme.
- Consistency in colour scheme between the parts of the app.
- All icons in "one family of expression", with transparent backgrounds.
- High contrast between one-coloured icons and button backgrounds.
- No horizontal scrolling, minimal vertical scrolling.
- Identical branding in all screens (incl. the app logo where appropriate).
- No "bells and whistles", such as decoration elements, disturbing or childish animations, clip art humour / cartoon style, smileys etc.
- Avoid over-loading the screens.

Part E: Other

- Alt-txt for figures.
- H1-H3 tag for headers.
- Text as text (not pictures of text) for browser translations etc.
- Figures/photos that download quickly (size of the file).
- Picture material in one and same style for one purpose (photos, screenshots).
- Language choices.