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EXPLORING DIGITAL INTERVENTIONS WITH DEAF PEOPLE IN BANGLADESH FROM THE PERSPECTIVES OF SUSTAINABILITY PILLARS

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EXPLORING DIGITAL INTERVENTIONS WITH DEAF PEOPLE IN BANGLADESH FROM THE PERSPECTIVES OF SUSTAINABILITY PILLARS

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ABSTRACT

This study examines how digital interventions designed with deaf people in Bangladesh can address the three pillars of sustainability, social, economic and environmental, using the double-diamond co-design method. In the 'discover' and 'define' phases, we ran ten workshops across five districts (125 participants: 109 deaf people, 16 caregivers) and conducted ten stakeholder interviews. Thematic analysis revealed that social-service needs, especially health (including mental health) and education, dominate deaf participants' priorities, while environmental considerations were less prominent. Key cross-cutting issues include stark digital inequities (varying device access and literacy), a severe shortage of accredited sign-language interpreters, platform and affordability barriers, and negative societal attitudes that constrain uptake. Based on these insights we identify five design problems that will guide the next 'develop' and 'deliver' phases: (1) negligible digital health services for deaf people; (2) intra-group digital inequity; (3) unsustainable reliance on scarce interpreters; (4) unequal affordability and accessibility of platforms; and (5) limited societal empathy among key service providers. We propose prioritising co-development of low-cost, shareable digital mental-health interventions for digitally literate deaf youth while engaging government, NGOs and industry to enable inclusive scale-up.

Introduction

The sustainability pillars indicate the importance of economic, social, and environmental considerations (Purvis et al., 2019; Duić et al., 2015) for developing and designing different actions and interventions for holistic individual human development (Dalampira and Nastis, 2020). Consequently, these three pillars are widely used globally in designing different interventions for improving the lives of individuals (Purvis et al., 2019; Matthey-Junod et al., 2022; Mulder-Nijkamp, 2018). The three pillars of the sustainability framework as an interrelated concept (Dalampira and Nastis, 2020; Clune and Zehnder, 2018) have been referred to by numerous academic literatures in the context of human and community development (Dalampira and Nastis, 2020; Dunmade, 2002; Rodríguez-Serrano, 2017). The concept could be more relevant for individuals in the disadvantaged groups of society who are more exposed to economic, social and environmental risks but less capable of utilising opportunities than others due to their socio-economic and geophysical conditions. Within those groups, people with physical disabilities are further disadvantaged since most of the interventions and services designed are for those without physical disabilities (Devandas, 2017; Krahn et al., 2015). In low-resource country settings, the challenge becomes acute for people with disabilities (Kakooza-Mwesige et al., 2022; Morgado-Ramirez et al., 2020).

Bangladesh, as a least developed country, is a low-resource country setting where the government and development agencies have been trying to tackle different development challenges. However, achieving high-income status by 2041 is on the development agenda of Bangladesh through ensuring inclusive sustainable development (Pal and Sarker, 2023). There is a wider acknowledgment that this depends on developing the capacities of the most disadvantaged and excluded section of the population based on an innovative knowledge economy. Persons with disabilities are a section of the people in Bangladesh, with a considerable number requiring targeted interventions to become part of the development process (Al Imam et al., 2022). According to the last World Report on Disability published in 2011, there are around 16 million people with disabilities in Bangladesh, which accounts for almost 10 per cent of the total population (Sultana, 2010). It is therefore highly important to include this large section of the population in the transformative development process by taking different initiatives for them. While focusing on the capacity building of the person with disabilities, as indicated above, vulnerabilities and opportunities can be considered from the perspectives three sustainability pillars (economic, social, and environmental).

In this regard, digital interventions or information and communication technology (ICT)-based initiatives have been highlighted in academic literature for economic development, social and human development, and addressing environmental impacts separately for specific disadvantaged and excluded sections of society including persons with disabilities (Prabawa, 2022; Khetarpal, 2014; Mavrou et al., 2017; Manzoor and Vimarlund, 2018). However, the literature has not highlighted the role of digital interventions holistically by considering the perspectives of the three sustainability pillars in an integrated manner. This is highly valid for the deaf people in Bangladesh since no academic study was conducted with them to understand their perspectives on digital interventions in addressing the sustainability pillars and subsequently co-designing appropriate interventions. Besides, the current policies and action plans of Bangladesh did not look at the issue and did not aim to co-design appropriate digital interventions with deaf people.

Since the 'double diamond' research process facilitates the co-design of interventions through defining design problems for interventions with a particular group of people or users and subsequently co-developing the interventions with them for delivery, our research used this research process with deaf people in Bangladesh to co-design digital interventions. However, as initial steps of the process, we completed the 'discover' and 'define' phases of the research process and defined the design problems for co-developing and delivering appropriate digital interventions for deaf people in Bangladesh in the final phases of the 'double diamond' design process. This paper presents the insights of the first two completed phases of the design process by indicating the sustainable digital interventions explored with the deaf people in Bangladesh and highlighting the synthesis of design problems developed with the deaf people and relevant stakeholders.

Literature review

In this section, we have reviewed the prior literature on digital interventions for deaf people by associating those interventions with three sustainability pillars. This has provided us with insights into the most prominent and the least prominent pillars according to the academic literature, as well as the range of digital interventions. We also got insights into the design process behind suggesting digital interventions to understand the level of engagement of deaf people and related stakeholders. Since our research focus is on deaf people of Bangladesh from the perspective of sustainability pillars, in this section, we have separately presented the related academic works in Bangladesh. This has offered us insights into research gaps in Bangladesh in comparison to other contexts.

Digital interventions for deaf people

Since deaf people struggle to hear and talk, digital or ICT interventions predominantly incorporate visual means of communication, where the use of sign language and text replaces the audio feature of communication. Moreover, people without hearing and speech impairments also struggle to communicate with deaf people due to not knowing sign language unless they have deaf people as close relatives. Therefore, digital interventions are also designed for those without impairments by converting sign-language-based visual communications of deaf people to audio-based and text-based communications. In this regard, several studies (Anderson et al., 2017; Xia et al., 2022) highlighted the sign language recognition applications that can interpret sign language gestures and translate them into text or speech, facilitating communication between deaf individuals and those who don't understand sign language. While sign language recognition applications could be used for communications related to all sustainability pillars, most of the academic literature highlighting the intervention did not specifically discuss it from the perspective of any pillar (Rastgoo et al., 2021; Wadhawan and Kumar, 2021). However, some studies covered social service-related contexts for using sign language recognition applications, like the use of the application by health professionals in offering health services to deaf people (Xia et al., 2022).

It is to be noted that the potential application to become a standardised one faces multiple challenges due to diverse human body parts features and variations of sign languages in different contexts (Rastgoo et al., 2021). Moreover, commercialisation of the application has been found expensive due to the cost involved in data acquisition by using good devices. Researchers have also been using varied methods in developing sign language recognition applications (Anderson et al., 2017). We identified that some researchers only engaged sign language interpreters in their

co-design approach to develop sign language recognition applications, while some of them also engaged deaf people in the design process (Saggion et al., 2021; Al-Nafjan et al., 2021).

Video Relay Services (VRS) is another digital intervention highlighted in the literature that allows deaf individuals to communicate via sign language with the help of a sign language interpreter who appears on a video screen. This service enables deaf people to make video phone calls or join in video meetings and participate in conversations with others who do not know sign language, since the presence of the sign language interpreter at the video call mitigates the shortcomings of not knowing sign language by others (Bower, 2015; Warnicke and Plejert, 2012; Wessling and Shaw, 2014). While using VRS, deaf people use visual/gestural sign language on the video platform (via phone or other digital devices like a computer), and sign language interpreters use verbal/auditive language on the telephone/mobile phone/digital device (visual or non-visual) to relay the message to another individual who does not know sign language. That individual then uses verbal/auditive language on the telephone/mobile phone/digital device (visual or non-visual), which the sign language interpreter relays to deaf people by using visual/gestural sign language on the mobile phone/digital device (visual only) (Warnicke and Plejert, 2012).

To use VRS, deaf people and the sign language interpreter must have access to a mobile phone or digital device with video facilities and Internet services since they are in separate locations (Rivas Velarde et al., 2022). Such access to digital devices and services becomes challenging in some low-resource settings. Besides, qualified and accredited sign language interpreters are needed to utilise the full potential of video relay services, and the absence of an adequate number of sign language interpreters in a context makes VRS less viable. Moreover, emotional stress and burnout of sign language interpreters can also affect the quality and sustainability of VRS (Wessling and Shaw, 2014; Oldfield, 2010). Similar to the literature on sign language recognition applications, academic literature has also not notably focused on VRS regarding all sustainability pillars. However, some studies highlighted the usefulness of VRS in providing education services to deaf people (Cavender et al., 2010), health services by doctors (Kushalnagar et al., 2019), or getting services from law-enforcing agencies (Skinner et al., 2021). Based on these studies, we argue that VRS could be used for communications from the perspective of any sustainability pillar.

Considering the barrier to engaging sign language interpreters as well as the cost involved in using video-based interventions, Text-to-Speech (TTS) and Speech-to-Text (STT) Apps have also been used as other digital interventions for communications with deaf people (Adekola et al., 2021). While sign language interpreters are not needed, TTS translates text into speech in a human language format, while STT converts speech into text in a human language format. Since TTS and STT apps convert spoken language to text and vice versa, those who can speak and hear can communicate with deaf individuals in real time. Besides, some deaf individuals struggle to properly handle their arms and use sign language. For them, digital interventions like VRS may not work, but TTS and STT apps may provide them some respite (Saini, 2022). However, STT apps sometimes face challenges in recognising voice and converting to text since the speech of everyone may not be understandable, and there may be noise in the surroundings. Besides, the microphone performance of different digital devices is not the same in capturing speech. Consequently, words are omitted or distorted in converted texts, and deaf people may not get the communication properly (Lee and Park, 2021).

Another challenge of STT apps is the difficulty of distinguishing voices when several people are talking at the same time (Seebun and Nagowah, 2020). Moreover, variability in the speech patterns of speakers and their characteristics, including accent, makes it difficult to standardise the speech in different STT apps (Prasad, 2015). We have not found any academic literature related to TTS and STT apps for deaf people that includes all sustainability pillars. However, some studies found that these apps are useful for deaf people in providing education since they not only understand the speech of the text but also access the text as stored educational material in their digital device (Adekola et al., 2021; Seebun and Nagowah, 2020). Therefore, TTS and STS apps could also be used for communications from the perspective of other sustainability pillars to orient, train, or educate deaf people on economic, social, and environmental issues.

Adding captions or subtitles to videos and live presentations is another important digital intervention that allows deaf individuals to access content more easily, irrespective of the associated sustainability pillars, whether it's educational videos, movies, or live events (Glorioso et al., 2022; Díaz-Cintas, 2013; Neves, 2008). In Malaysia, a nutrition cartoon video developed with subtitles to encourage deaf children to eat nutritious foods received a positive reception from the children (Glorioso et al., 2022). The entertainment industry has become a major creator of numerous subtitled videos, and an increasing number of digital televisions have been providing deaf people an easier access to subtitled content by using remote controls with a subtitle button (Díaz-Cintas, 2013). However, using subtitles also comes with challenges since people with old analog televisions and older equipment are unable to access digital content with subtitles. Subtitle text needs to be standardised by experts and needs to be verbatim so that deaf people are not devoid of any spoken material. Moreover, the low literacy level of deaf people may reduce the effectiveness of subtitles and necessitate sign language-based intervention (Neves, 2008).

Along with the aforementioned digital interventions deliberately targeting deaf people with the adoption of special and customised technical design, different mobile apps for the education of deaf people have also been emerging over the years (David et al., 2023). These mobile apps are designed to teach various skills, from reading and writing to sign language, to deaf people. For example, the interactive mobile application "SmartSignPlay" uses an animated avatar to support the learning and practice of American Sign Language using signs. "Fingerspelling Tutor" is another mobile application that demonstrates fingerspelling by using a 3D animated character while including quizzes and practice lessons for deaf students (Constantinou et al, 2020). The GeePerS*Math game was designed to teach deaf and blind school children from 4th to 6th grades as they learn through playing the games (Shelton and Parlin, 2016). As academic literature highlighting these applications has a strong focus on education, the perspectives of sustainability pillars need to be drawn from an educational impact perspective in relation to different pillars. It should be noted that despite these numerous mobile applications being designed for the education of deaf individuals, utilising these digital interventions requires access to a smartphone and Internet access, which may be challenging for deaf students in low-resource settings.

The final major digital intervention highlighted in academic literature is text-based communication through the use of social media and messaging applications that do not need any additional design consideration like other digital interventions (Ali and Aydah, 2012; Lagayan, 2019). Most social media platforms like Facebook and WhatsApp support text-based communication, which is particularly helpful for deaf individuals, along with using short message service (SMS) in their day-

to-day interactions. The use of SMS is important for deaf people who are unable to use messaging options of social media platforms since they require access to a smartphone and the Internet, while SMS can be used from any type of phone (Ali and Aydah, 2012; Lagayan, 2019). However, in the case of communicating with deaf people by using only texts on different platforms, persons without hearing and speech impairments need to be aware that the lexico-semantic features of the language or the meaning of words to deaf people could be different. In text-based communication, deaf people may lack words to express their feelings and sometimes use paralinguistic signals like emojis (Parmisana and Badilla, 2022). Therefore, it cannot be assumed that deaf people will understand text-based social media posts or other communications straightaway, or that their text communications will be understood without difficulties. Development of any text-based digital communication for deaf people, therefore, needs their participation, and it can be customised for any of the sustainability pillars.

Overall, our review of related academic works on digital Interventions for deaf people indicates that substantial work has been done in this regard. A considerable number of academic works involved deaf people, mostly at the time of applying the initially designed digital intervention. However, a lesser number of academic works indicate that deaf people were engaged in all steps of the design and delivery phases. Besides, the digital interventions for deaf people were hardly designed and delivered by considering all three sustainability pillars in an integrated manner.

Deaf people in Bangladesh and the role of digital interventions

Since Bangladesh has around 2.6 million deaf people (Islam et al., 2018), digital interventions designed from the perspective of sustainability pillars are highly important for the country. This is more significant considering Bangladesh's status as a least-developed country where economic advancement and equality have not been achieved for a large number of its citizens (Jahan, 2022). Some sections of the population are socially marginalised to an alarming extent (Diwakar, 2023), and environmental stress is substantial due to climate change impacts and biodiversity loss (Ali, 1999; Hasnat et al., 2018). In this setting, deaf people were not historically prioritised in development interventions, as the focus of development interventions was on utilising the physical abilities of those who do not have any physical impairment (Alauddin and Joarder, 2004; Sultana, 2010).

Deaf people have been facing serious social exclusion in Bangladesh. Deaf women are one of the major groups who face sexual violence but receive inadequate legal protection in the judicial system (Sultana, 2010). Due to social exclusion, poverty is a common feature of deaf people in Bangladesh, and many of them live in loneliness and frustration (Tarafder et al., 2015). However, the situation has been gradually changing as the country aspires to become a developing country and subsequently a developed country (Pal and Sarker, 2023). The targets set to achieve Millennium Development Goals and ongoing sustainable development goals require the inclusion of disadvantaged communities in Bangladesh, including persons with disability and deaf people (Ashraf et al., 2019). Consequently, when Bangladesh adopted the 'Digital Bangladesh' vision in 2009 and subsequently expanded its digital interventions, different digital interventions were considered to include the deaf people so that development targets as well as targets related to digitalisation could be achieved together (Aziz and Naima, 2021).

Regarding digital interventions for deaf people in Bangladesh, we have identified a notable body of academic literature evolving in line with the 'digital Bangladesh' vision and the related expansion of access to digital technologies by the common citizens (Islam et al., 2018; Rony et al., 2018; Shamrat et al., 2021). Considering the acute shortage of sign language interpreters in Bangladesh and the lack of sign language skills of relatives or family members of deaf people, a system was proposed by using a convolutional neural network (CNN) recognising hand gestures and classifying the characters, and vice versa. While the proposed system falls within the domain of works on sign language recognition applications, the purpose of the system was to recognise Bangla sign language and convert it to Bangla language, and vice versa, since Bangla language and sign language are different from other languages and sign languages (Rony et al., 2018). By using a deep convolutional neural network, a similar type of work was also done to recognise Bangla numerical sign language. The experimental framework was used to learn from ten sets of input images with 31 distinct numerical hand signs and compared the images to a previously trained dataset, finding a significantly high degree of accuracy (Shamrat et al., 2021).

To complement the effort related to Bangla sign language recognition system development, an attempt was also made by researchers to prepare a complete publicly available dataset (named Eshara-Lipi) that arguably contains all Bangla sign language characters (Islam et al., 2018). Overall, we found that there was a significant focus on Bangla sign language recognition in related academic literature specific to deaf people in Bangladesh (Hasan and Ahsan, 2019; Alam et al., 2021; Youme et al., 2021; Yeasin et al., 2019), while not finding strong references to sustainability pillars.

Other than the dominant focus on Bangla sign language recognition applications, research in Bangladesh was also focused on developing mobile applications for deaf people. One research study followed a co-design approach with deaf people from a religious group who have a specific interest in receiving communications and materials related to their religion. The mobile application, named Kotha Bondhu, was designed based on the feedback of deaf people and had different features, including audio, video, and text (Hossain et al., 2020). Since the major focus of the application was to facilitate basic communication between deaf people and others who do not know sign language, the application had video clips of different signs accompanied by Bangla audio and text of those signs. When a deaf person uses a sign to communicate, others can match that to related audio and text by looking at the related video clip. Since others who do not know sign language, to communicate something to deaf people, they refer to the audio and text to show the related video clip of a sign to a deaf person (Hossain et al., 2020). While instant communication is challenging when using the application, it facilitates basic communication in the setting of large religious gatherings, where having sign language interpreters is not feasible for all communications.

In the Bangladesh context, another study focused on designing a sensor-based hand glove for deaf people. It is supported by an Android mobile phone application that receives voice and converts it to speech. The speech is then sent to the hand glove through a wireless communication system, and the glove's LCD shows the result to a deaf person. When the deaf person moves his/her hand, based on the valid movement, letters and words are detected and outputs are displayed on the Android mobile phone of the person without speech and hearing impairments (Mamun et al., 2017). While the study referred to Bangladesh, the digital intervention discussed could be related

to any context. Besides, although no perspective was provided on the cost aspect of the intervention, it was acknowledged that the sensor struggles to detect differences between letters, and there are inconsistencies in sensor values (Mamun et al., 2017).

Related research on speech recognition and conversion to sign language for Bangla-speaking people was also done, considering the complexity of the language to work with. A smartphone application was designed to provide a two-way communication platform for deaf people and people without impairments (Shahriar et al., 2017). As the application is based on a speech-to-sign language system and a text-to-speech system, a person without impairment speaks in Bangla, and the system recognises Bangla speech and converts it to text. In the application, the text is then translated into Bangla sign language based on an established algorithm, and a deaf person will receive static images in the application containing sign language. The deaf person then communicates by typing Bangla text, and another system converts that text to Bangla speech in the application for a person who does not have speech or hearing impairments. However, it is acknowledged that static images of Bangla sign language may be difficult to understand by deaf people (Shahriar et al., 2017).

In summary, our review of academic works on digital Interventions for deaf people in Bangladesh indicates that researchers have been increasingly working on this area, but the focus has been strongly on the sign language recognition system. We have not found that while discussing that system, as well as other interventions, researchers conducted notable analysis on the cost of developing the interventions or the socio-economic readiness of deaf people to adopt the digital intervention. Although some academic research involved deaf people, most of the research did not follow a strong co-design process with deaf people in exploring suitable digital interventions and designing those. Besides, similar to other academic literature discussed in the previous section, when designed and delivered, the digital interventions for deaf people in Bangladesh hardly considered the three sustainability pillars in an integrated manner.

Methodology

Design method

Considering the inadequacy of academic research in Bangladesh in discovering suitable digital interventions with deaf people from the perspective of sustainability pillars and subsequently designing those together with them for delivery, we adopted the 'double diamond' design method to facilitate a co-design process by following recommended steps. In this regard, our initial research presented in this paper used the double diamond design method to define the design problems related to digital interventions by engaging deaf people, their family members, and related stakeholders in Bangladesh. We did this through workshops with deaf people and their family members and interviews with stakeholders working with deaf people. The workshops aimed at scoping out the digital intervention options, needs, and capacities of deaf people from an integrated perspective, combining economic, social, and environmental considerations. The interviews explored the insights of related stakeholders on potential design features of digital interventions to mitigate the challenges identified during the workshops.

During the initial phases of our research, the main aim was to identify digital intervention options and the needs of deaf people from the perspective of sustainability pillars, along with identifying their associated capacities and challenges of using those interventions. While doing so, the

research also aimed to explore the potential facilitating role of the government and other stakeholders in adopting digital interventions by deaf people from the perspective of sustainability pillars.

Double diamond research method

The double diamond design method is structured in four phases: discover, define, develop, and deliver (Wang et al., 2023). The method follows a process of divergent and convergent thinking since, after identifying the potential design challenges, divergent thinking needs to be applied during the 'discover' phase. This phase is part of the first diamond, along with the 'define' phase. The first phase is about familiarising, discovering, and empathising with the problems or challenges of the target group concerning a design problem, which in our case is suitable digital interventions for deaf people in Bangladesh, addressing the sustainability pillars. The second phase, or 'define' phase, is also part of the first diamond but is related to convergent thinking, as in this phase, data from the first phase is analysed to narrow down the information and create diverse profiles of persons from the target group. After this phase, the initially drafted design brief needs to be reviewed and updated for the next two phases (Pyykkö et al., 2021). While we intend to cover all four phases, we have completed the first two phases in the first diamond so far, and this paper presents the design problems based on those two phases (known as the problem space).

In the 'develop' phase of the double diamond design method (part of the second diamond), based on the design problems, divergent thinking is applied again to generate ideas through ideation workshops engaging target groups and subsequently design pilots or prototypes with them. During the 'deliver' phase, pilots or prototypes are tested and often re-prototyped by applying convergent thinking. The second diamond, comprising the develop and deliver phases, is known as the solution space since co-developed solutions are delivered afterwards. Observing the effectiveness of the solution concerning the design problem is not within the scope of the double diamond design method since that requires longer time engagement for evaluation (Pyykkö et al., 2021). As indicated, in our initial research, we have not gone to the solution space as we decided that solution orientation needs to be specific to a particular issue since considerations of sustainability pillars may generate diverse perspectives in the problem space (i.e., the first diamond).

The decision to use the 'double diamond design method' has been guided by its effective use to co-design interventions with persons with disabilities due to its inherent feature of inclusiveness. A study using the method with people with intellectual disabilities found that this method facilitates sensitivity to share power and utilises diverse communication modalities. It offers space to participants to think freely and speak freely when the group dynamics are properly managed (Knevel et al., 2022). Another study also found the method effective in co-developing orientation guidance in wearable human–machine navigation systems with participation of some blind and visually impaired people (Zhang et al., 2019). Considering some of these studies conducted with persons with disabilities by effectively using the 'double diamond design method' along with co-design works done with other groups of society, our research team chose the design method that could empower deaf people in the co-design process.

Recruitment and participants during the 'Discover' phase

In our research, the 'discover' phase involved workshops with deaf people as well as their family members and interviews with the stakeholders to ensure a bottom-up process and engage all relevant actors to comprehensively understand the digital intervention design problems from the perspective of sustainability pillars. Since our work engaged participants with impaired capacity for communication, it was considered a project with more than low risk, and it was discussed at a full human research ethics committee meeting of our host institution. Based on the review committee members' review and feedback, we had to amend our explanatory statements and consent forms, especially for deaf people, so that they could be easily communicated by using sign language in case any participant does not have the literacy to read the documents. We were also allowed by the committee to financially compensate our research participants for offering their time after we satisfied the committee that no conflict of interest would arise due to the payment to participants. It was a fair arrangement to engage the research participants since the research did not have any scope to offer immediate research benefits to the participants. After getting the full ethical approval for our work, during the workshops, we obtained the consent of deaf participants and video recorded the consent of those who were unable to read and sign a consent form. Since we had to video record the workshops due to the use of sign language, we had the full consent of participants to use their photos and videos in our research, papers, reports, and documentation.

About recruiting participants from diverse geographic locations in Bangladesh, we considered the diverse socio-economic situations and environmental vulnerabilities of Bangladesh. Accordingly, we conducted the workshops in five different districts of Bangladesh: Dhaka, Dinajpur, Khulna, Rangpur, and Sylhet districts. As shown in Figure 1, all five districts are in medium to high multiple environmental hazard zones (Barua et al., 2021) as these locations face compound impacts of flood, earthquake, tornado, and cyclone. It indicates that deaf people from these locations face environmental vulnerabilities, and the environmental pillar is relevant for them in designing any intervention, including digital ones. However, to ensure further variations in terms of socio-economic situations, five districts were also chosen since the poverty situation varies in these districts. As shown in Figure 2, Rangpur has a poverty headcount ratio (the percentage of the population living below the national poverty lines) of 46%, whereas Khulna and Dinajpur districts have ratios of 39% and 38%. Sylhet and Dhaka are better-off districts with poverty headcount ratios of 24% and 16%. From the three districts with a high poverty headcount ratio, deaf people and their family members joining the workshops were from rural areas. In Sylhet and Dhaka (which is also the capital of Bangladesh), workshop participants were from urban areas. We ensured such variations to get diverse economic and social perspectives, considering our focus on the sustainability pillars. At each district, we conducted two workshops by engaging a Bangladesh-based disability organisation that facilitated the workshop by involving sign language interpreters working for the organisation. That organisation had the contact lists of deaf people in the districts based on their work in those locations.

In total, 109 deaf participants and 16 caregivers of deaf participants joined ten workshops organised in five districts. Out of 125 participants, 55 participants have access to smartphones and can use smartphones. The rest of the 70 participants either have feature phones or do not have any phone. 29 participants out of 55 participants who have smartphones are young people aged under 30 years.

Figure 1: Five districts covered in the research indicated in the multi-hazard zoning map of Bangladesh (Barua et al., 2021)

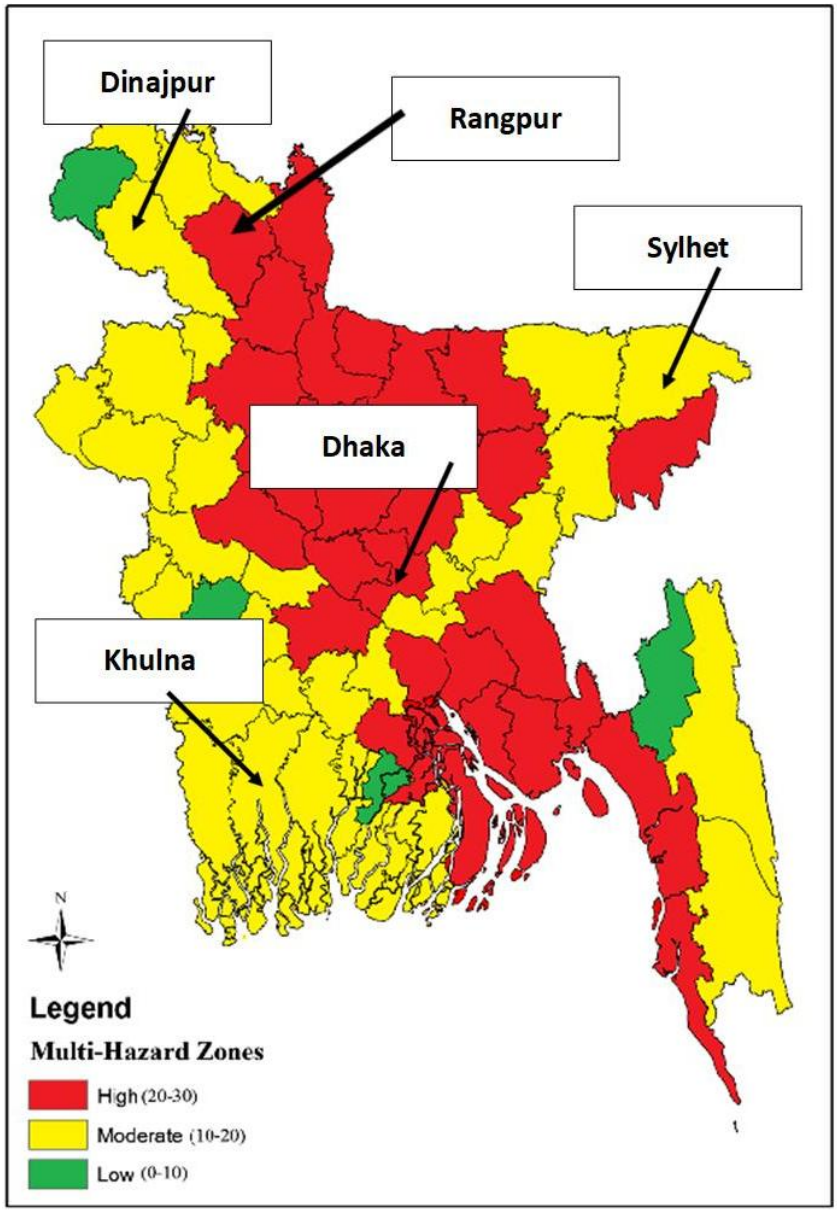
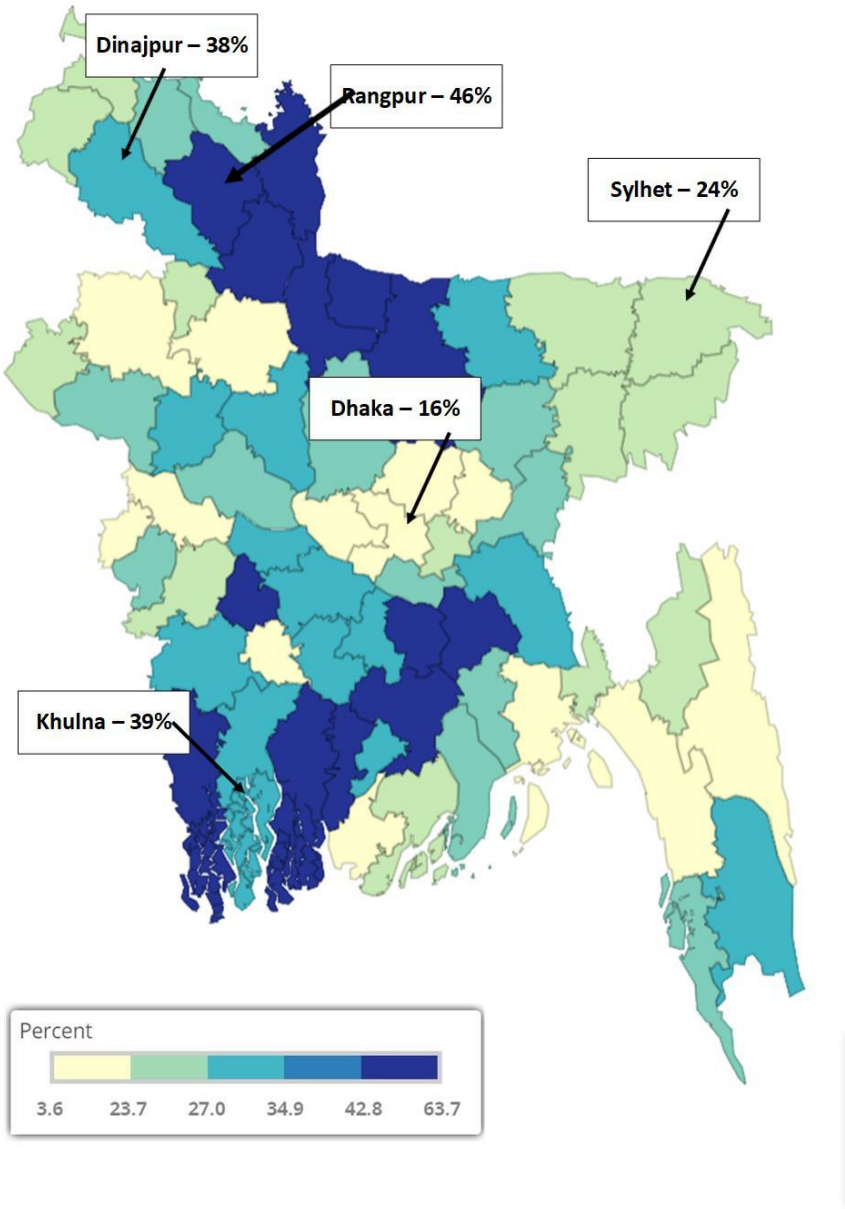


Figure 2: Five districts covered in the research are indicated in the poverty map of Bangladesh with the poverty headcount ratio [Public domain], via World Bank. (https://designstudio.worldbank.org/maps/2016/3323/map.html)



Areas of exploration during the 'Discover' phase

During the workshops with deaf people and their family members at the 'discover' phase, we tried to understand the relationship with three different sustainability pillars through some sub-dimensions. Regarding the social dimension, we focused on three sub-dimensions of social services: health services, education services, and the social safety net. We explored what social services deaf people access and what digital interventions are available for them to access those services. We then focused on their needs and capacities to use existing and potential digital interventions along with related opportunities and barriers. Regarding the economic dimension, we followed a similar pattern of discussion with the major focus on income opportunities of deaf people and their existing access to finance. With the environmental dimension, we explored the

services related to addressing environmental stress and accessing natural resources like agricultural land, water bodies, etc. As indicated, the discussion on digital interventions was followed by the discussion on any sustainability pillar. At each of the workshops, we had six to twelve deaf participants and their family members. We also had two sign language interpreters, at least one assistant to capture the workshop discussions, and at last one research team member as the overall facilitator of the workshop. Figure 3 shows one of our workshop discussions in the Sylhet district, where a deaf person is expressing his opinion by using sign language. The sign language interpreter instantly narrated that for audio recording, while we also video recorded the workshop.

Figure 3: A deaf workshop participant is expressing his views by using sign language at one of the workshops in Sylhet district

In addition to ten workshops conducted in five districts, during the 'discover' phase, we conducted ten stakeholder interviews with participants from ten different organisations that are working for the welfare of deaf people in Bangladesh and are aware of the digital landscape of Bangladesh. Among them, one participant was from a government organisation, two participants were from organisations working as membership organisations of deaf people, one participant was from a small enterprise promoting entrepreneurship of deaf people, one participant was from a health service provider of deaf people, four participants were from local non-government disability organisations, and one participant was from an international non-government disability organisation. The stakeholders covered different sectors like health, education, employment, and natural disasters that were focused on in the research from the perspective of the sustainability pillars. During interviews, we highlighted the similar discussion points of the workshops by discussing the available and suitable digital interventions for deaf people in Bangladesh from the triple bottom line perspective.

In Table 1, we have mapped ten workshops with ID (first two columns) and profiles of ten stakeholders with ID.

Table 1: Mapping of workshops and interviewees

Workshop	ID	Interviewee's organisation	ID
Dinajpur-1	W1_DP1	Government	I1_GO1
Dinajpur-2	W2_DP2	Deaf organisation -1	I2_DM1
Dhaka-1	W3_DH1	Deaf organisation -2	I3_DM2
Dhaka-2	W4_DH2	Enterprise	I4_EP1
Khulna-1	W5_KH1	Health service provider	I5_HS1
Khulna-2	W6_KH2	Local NGO-1	I6_LN1
Sylhet-1	W7_SH1	Local NGO-2	I7_LN2
Sylhet-2	W8_SH2	Local NGO-3	I8_LN3
Rangpur-1	W9_RP1	Local NGO-4	I9_LN4
Rangpur-2	W10_RP2	INGO	I10_IN1

'Define' phase

Due to the engagement of deaf people at the workshop and the use of sign language, we video recorded all workshops to analyse the data during the 'define' phase of our design process. During this phase, sign language interpreters transcribed all workshop and interview inputs in Bangla, and our research team translated those into English. The analysis for the workshop and interview data was executed using thematic analysis, as Boyatzis (1998) indicated that this analysis assists in encoding qualitative information requiring an explicit code. The explicit code could be a list of themes or a complex model of interrelated themes, indicators, and qualifications (Boyatzis, 1998). Based on the themes, thematic analysis is also considered a systematic approach to interpreting information while finding commonalities, differences, relationships, and overarching patterns to define any design problem (Boyatzis, 1998). Themes can be inductively generated from the raw information or deductively generated from theory and prior research (Boyatzis, 1998). During the 'define' phase, we used a deductive approach to generate themes based on our research focus on suitable digital interventions for deaf people in Bangladesh from the perspective of three sustainability pillars.

By using the deductive approach, three considerations, economic services, social services, and environmental services, were identified as three primary themes. Under social services, (i) health services, (ii) education services, and (iii) social safety net were considered as three secondary themes. Two secondary themes under the economic service primary theme were generated as (i) income opportunities for deaf people and (ii) access to finance for deaf people. About the environmental services primary theme, two secondary themes were (i) services related to addressing environmental stress and services related to (ii) accessing natural resources like agricultural land, water bodies, etc. As indicated, the discussion on digital interventions was followed by the discussion on the sustainability pillar.

In line with the research focus, our five primary cross-themes related to all the seven secondary themes were (i) digital intervention needs of deaf people in Bangladesh, (ii) digital intervention options for deaf people in Bangladesh, (iii) capacities of using digital interventions by deaf people in Bangladesh, (iv) challenges of using digital interventions by deaf people in Bangladesh, and (v) facilitation by the government and other stakeholders in adopting digital interventions by deaf people in Bangladesh. The qualitative data coding structure shown in Table 2, comprising all the primary themes and secondary themes, was subsequently used for our research to map out the related digital interventions indicated by deaf people, their family members, and stakeholders. During the 'design' phase, we manually interpreted and analysed the information from workshops and interviews according to the coding structure.

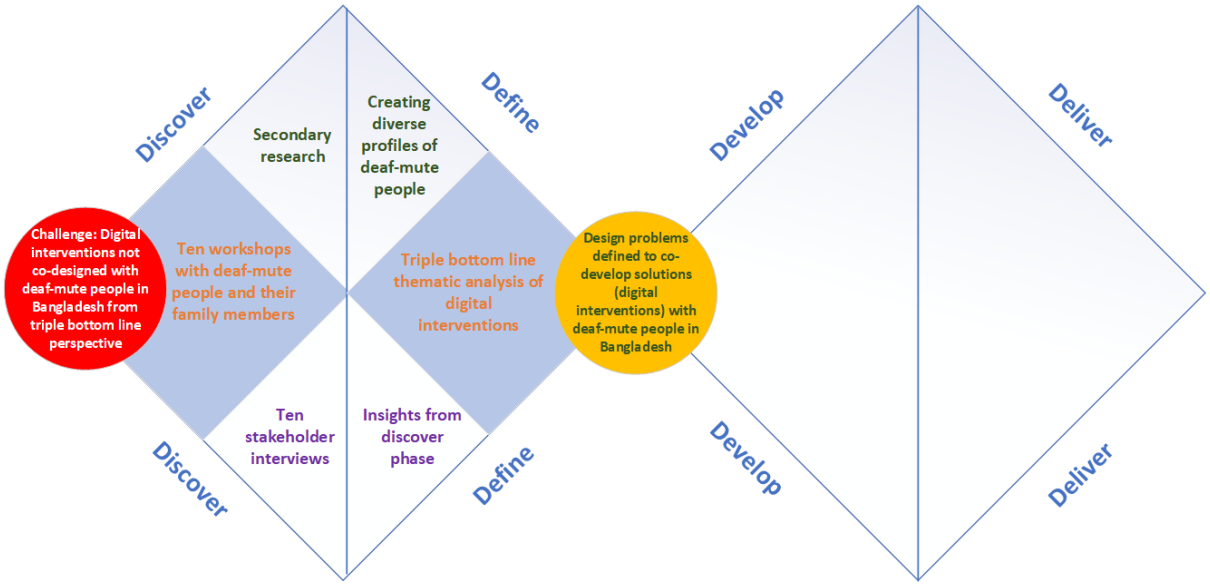
Table 2: Coding structure used for mapping workshop and interview data

Digital interventions	Social services			Economic services		Environmental services	
	Health	Education	Safety net	Income	Finance	Disaster	Natural resource
Options							
Needs							
Capacities							
Challenges							
Facilitation							

At the end of the 'design' phase, the manually analysed information based on the coding structure provided us with the design problems refined from the initially identified challenges to work on during the 'develop' and 'deliver' phases of the solution stage in the double diamond design method. While the design problems were derived from the inputs of deaf research participants and other stakeholders, after defining the design problems, one online consultation was held with a smaller group of deaf participants with support from a sign language interpreter to discuss the defined design problems. They reaffirmed the design problems derived from the analysis. Due to logistical and funding challenges, our research team couldn't discuss the design problems with all the participants of the 'discover' phase.

Figure 4 captures the double diamond design method that we intended to follow in our research, while elaborating first two phases in detail since we have completed those two phases at this point.

Figure 4: ‘Discover’ and ‘Define’ phases of the Double Diamond Design Method followed in the research



Findings

The results revealed strong social services-related considerations related to the sustainability pillars in using and requiring digital interventions by deaf people and their family members in Bangladesh. Consideration of economic services is also present due to the increased engagement of deaf people in income-generating activities. Stakeholders were also more focused on those two considerations. While environmental consideration from deaf people and their family members was significantly low, stakeholders provided some key insights about potential digital interventions to be designed for deaf people in Bangladesh. Digital inequality influenced by socio-economic inequality was also evident when digital intervention needs, options, capacities, and challenges were explored. In the following sections, we elaborate on these key findings.

Digital intervention options for deaf people in Bangladesh

As we tried to understand the digital options deaf people currently have from the perspective of sustainability pillars, at most of the workshops, deaf participants and their family members highlighted the options related to education services. At some workshops, digital intervention options to access economic services were also discussed, while there were discussions on natural disaster-related services at some workshops. Interestingly, at the workshops, participants did not notably indicate that they currently have significant digital intervention options related to health services from service providers. Overall, the workshop discussions indicated that deaf people in Bangladesh have significantly inadequate options for advanced digital interventions from the perspective of sustainability pillars. At several workshops, especially the ones in Rangpur, Dinajpur, and Khulna districts, where participants were from rural areas, a significant number of deaf people did not have access to any digital device. Due to their low familiarity, some deaf participants were unable to discuss any digital interventions available to them from the perspective of the sustainability pillars. One parent at the W1_DP1 workshop in this regard mentioned:

> Many deaf people do not know how to use a computer. If you do not know it, how will they know its usefulness?

However, the participants from the capital city of Dhaka could substantiate their experiences of having some options related to digital interventions since all the participants have access to digital devices. For example, about receiving education services, one W4_DH2 workshop participant highlighted that she attended a training program on computer courses organised by the Bangladesh Computer Council, where the audio-visual course materials had sign language interpretation with videos. Another workshop participant at the same workshop mentioned that some simple, informal digital interventions by her teacher and classmates enhanced her study experience at the university. Initially, she struggled to understand anything in student group discussions since her classmates did not know sign language. Her teachers could not help her in this regard, and she often missed important announcements regarding examinations and assignments. When she had smartphone access and started to use Facebook, her teachers and classmates included her in a Facebook group where they posted important study materials and announcements. As the study experience of the participant significantly changed, she mentioned:

> Before joining the Facebook group, I was always confused. I had to partake in the midterm examinations immediately, as I did not have any information. Sometimes, course teachers announce for examination just before the day of the examination. The class representative shared the information in the class, but I did not know. I often missed it. It happened to me many times. When I started joining the Facebook group, it appeared very accessible to me. I could access all the notices for examinations and other course materials. Facebook was like heaven to me.

From education service and income generation perspectives, a participant at the W4_DH2 workshop mentioned that deaf people can follow training videos on graphic designing by looking at the steps followed and can practice the same on their personal computers. The participant emphasised that simply having digital access enabled some deaf people to become graphic designers and earn an income. She indicated that deaf people are working as graphic designers from home and do not significantly need to interact face-to-face if someone can develop good skills as a graphic designer. Despite the digital intervention the participant referred to was not customised for deaf people, we note this as an important insight to identify the importance of self-explanatory training videos like the silent movies in the past. One W1_DP1 workshop participant (a parent) also highlighted that his daughter has excellent skills in painting. She looks at paintings available on the Internet and prepares her paintings by understanding the basics of drawing pictures. She does not need to communicate with anyone in this regard.

Although not particularly from the perspective of health services from third parties, a participant at the W4_DH2 workshop highlighted the importance of accessing digital devices and basic digital interventions like video calls or geolocation services like Google Maps are beneficial for the better mental health of deaf people. She mentioned that due to having a smartphone, she can remain connected to her parents and interact with them in sign language through video calls. She can also share her location from Google Maps with them if she feels lost or confused. She opined that the opportunity to access some of the basic digital interventions designed for smartphones can greatly

improve the mental health of deaf people and their parents. Another participant at the W6_KH2 workshop also mentioned that he has peace of mind due to using mobile phone technology since he can now interact with more people in group settings who do not know sign language, and he can send group messages to everyone or participate in online group discussions. Besides, the use of mobile phones in receiving social safety net-related payments was mentioned by participants of the W9_RP1 workshop. They highlighted that they receive disability allowance through mobile phones.

About receiving natural disaster-related services, a W5_KH1 workshop participant mentioned that although he does not get any text messages or early warning of natural disasters through his mobile phone, he has the option to be connected with his Facebook friends with hearing and speech impairments who post videos on warnings of natural disasters on Facebook by using sign language. At the W5_KH2 workshop, another participant mentioned that when natural disasters hit, they can take videos of the destruction and post them on Facebook to ask for any support needed. Another participant at the same workshop also highlighted the significant contribution of mobile phone communications during natural disasters, as deaf people try to support each other by providing information through video calls.

At the W7_SH2 and W9_RP1 workshops, participants indicated receiving digital health services during the COVID-19 pandemic. A W9_RP1 workshop participant mentioned that they received SMS alerts through mobile phones to join the vaccination program during COVID-19. A W7_SH2 workshop participant in this regard mentioned that the use of Facebook during the COVID-19 pandemic was useful for deaf people for sharing and receiving public health information. He also opened a Facebook page for deaf people to share information in sign language and was able to generate funding for the response effort for deaf people.

While discussing with the interview participants, I1_GO1 mentioned that deaf people who have literacy and access to digital literacy are currently availing of digital health interventions like telemedicine, messaging systems, and many other technologies to access health services from providers.

Digital intervention needs of deaf people in Bangladesh

Regarding digital intervention needs related to different services associated with sustainability pillars, most of the workshops highlighted the needs related to health services. There was negligible discussion on education services and income-generating opportunities, while other areas were not indicated by deaf people and their family members. Participants indicated that getting health services from doctors is the biggest challenge for deaf people, in case they do not have any family member available to act as a sign language interpreter to assist them. They indirectly hinted that video relay services (VRS) to be used more by health service providers so that deaf individuals can communicate with doctors or health professionals via sign language with the help of a sign language interpreter appearing on a video screen. A W3_DH1 workshop participant in this regard mentioned:

> I want something, an app, feature or anything like that in my mobile phone where there will be a sign language interpreter available who will translate for me and will act as a bridge to enjoy the services that I am looking for from the doctor.

A similar opinion was also expressed at the W4_DH2 workshop, where one workshop participant suggested keeping the sign language interpreter available at least one or two days every week at the video platform, considering the number of potential deaf patients and the low number of sign language interpreters in Bangladesh.

Another digital intervention needed at the W3_DH1 workshop was related to developing apps where deaf people can provide sign language input, and their health provider will get the message in converted speech or text. The indicated need is related to sign language recognition applications as explored in numerous types of research. This need was also mentioned by interview participant I3_DM2. However, deaf participants did not indicate that they are currently using any such application. One participant of the W6_KH2 workshop also mentioned that they need an interpretation feature to be introduced through a mobile application that interprets sign language and mediates the communication between a deaf person and a health service provider who does not know sign language. From a sales job perspective, a W6_KH2 workshop participant mentioned that an application for a deaf salesperson will be helpful if the customers can provide input by saying the product name and the deaf salesperson can receive that input in sign language to bring and sell the product to the customer. Another participant from the same workshop highlighted the need to add subtitles in health awareness videos on social media platforms like Facebook and YouTube, as he mentioned that those videos are of no use to deaf people as they don't understand the message entirely, while a simple addition of subtitles will let them remember the messages. In this regard, a W7_SH1 workshop participant indicated that a health awareness message-related video on a social media platform should always be made by engaging a sign language interpreter whose video should simultaneously appear with the video of the main speaker.

The issue of adding subtitles was also discussed at the W2_DP2 workshop from an education service perspective, where a participant indicated the need to add subtitles in different online class lectures available on social platforms. Although discussed from an income generation perspective, a W8_SH2 participant also indicated that there are different training videos available on digital platforms targeting to enhance income-generating soft and technical skills of job seekers and entrepreneurs. However, most of those videos neither have subtitles nor any embedded videos with sign language. A W6_KH2 participant highlighted this issue by saying:

> I can learn many things from YouTube. But the contents are not accessible. I do not understand what is discussed in the video. If the contents can be made accessible with appropriate means of communication, sign language or subtitles, for example, then it will be easier for me. So far, I have not been able to learn anything from YouTube.

A W7_SH1 workshop participant also mentioned that many class lectures can simply be made accessible by making videos of those lectures and adding subtitles, and embedding sign language videos to support deaf students. In this regard, about natural disaster-related services, participants at the W5_KH1 workshop further highlighted digital intervention needs since they are not currently getting adequate information conveyed in sign language on digital platforms, whereas significant visual contents are produced without considering the needs of deaf people.

About government hotline services, interview participant I1_GO1 mentioned that deaf people cannot take any benefits by calling that number due to their impairment. He mentioned that there is a need to ensure emergency video call services or text-based emergency services from the part of the government for deaf people. Besides, interview participant I9_LN4 highlighted that there is a need to convert all disaster-related terminologies into sign language and create accessible videos for deaf people.

Capacities of using digital interventions by deaf people in Bangladesh

In relation to the discussion on capacities of using digital interventions by deaf people in Bangladesh, deaf people and their family members have not significantly related their capacities to a specific sustainability pillar. They pointed out that when a deaf person has digital access, he/she can have the capacity to quickly use all features of the digital devices without much orientation. However, many deaf people do not have access to digital devices and do not have basic literacy. Therefore, a large number of deaf people in Bangladesh do not have the capacity to use digital interventions. Besides, despite having the capacity to use all basic features of digital devices, the capacity to fully utilise the digital interventions is hindered by online content produced without considering the needs of deaf people or having a significantly low number of people in society who have the sign language skill.

In this regard, a W6_KH2 workshop participant mentioned that despite having full capacity to use all features of her phone, she is only able to communicate with other deaf people and not with persons without hearing impairment, since they do not understand her gestures (also mentioned by a W8_SH2 participant). The phone becomes useless to her at that point. She therefore needs to have the capacity to write and communicate with others through a mobile phone. She also emphasised on literacy of deaf people to be capacitated to some degree to utilise digital interventions. However, she acknowledged that writing a huge amount of text is a time-consuming act, and it does not guarantee that the receiver of the text will pay full attention to the written text more than speech. Like many other workshop participants, she reiterated that having more people with sign language skills can help deaf people to fully utilise their capacity to use digital interventions. In this regard, another W6_KH2 workshop participant mentioned:

> I am capable of using video calling platforms, but just to communicate with my fellows with speech and hearing impairments. Other than this, this mobile phone does not benefit me much because much of the content it holds is not what I require. If any feature exists that would ease my communication barrier, then I would benefit in all the spheres of my life, including education, health, and the workplace. When I look at entertainment content, it does not entertain me anyway.

Despite the limitations, from a natural disaster service perspective, a W3_DH1 workshop participant highlighted the capacity of deaf people by saying:

> Now, many deaf people have smartphones in their hands, and all of them have a Facebook account. They are very much active in their Facebook groups, including other online communities. They share the media information about natural stresses in their community and make everyone aware of any potential risk by

> using sign language. We have made Facebook our sign language radio during natural disasters.

In this regard, deaf participants at the WP_DP2, W7_SH1 and W10_RP2 workshops indicated they use Facebook Messenger, WhatsApp, Imo, YouTube and TikTok and demonstrated what they are capable of doing with these applications. One participant at the WP_DP2 workshop mentioned that by getting support from his parents, he makes video calls with his teachers to understand different study-related issues. Interview participant I8_LN3 also mentioned that she observed extensive use of WhatsApp and Imo by deaf people in Bangladesh, mainly to communicate among themselves and share relevant materials. Interview participant I10_IN1 indicated that he observed deaf people share work opportunities in their WhatsApp groups and other social media and try to support each other through their active social network.

Besides, about seeking employment services by utilising digital interventions, a W5_KH1 workshop participant also highlighted that he is capable of applying for jobs online much more easily than paper-based applications. Another participant from the W10_RP2 workshop who works as a carpenter mentioned that his employer communicates with him through mobile text to come to work by indicating different locations of work locations and his current level of literacy is adequate to understand that text and go to his work locations. Some participants at the W7_SH1 workshop also indicated that they are capable of earning by making digital content for social media platforms, while most of the participants at the same workshop were unaware of such income opportunities.

Concerning the capacity of deaf people in using digital interventions, interview participant I2_DM1 opined that deaf people are generally creative and good at architectural design, graphic design, and painting. He mentioned that since deaf people are quick adopters of digital interventions, their capacities can be maximised if their creativity can be enhanced through digital interventions. Interview participant I4_EP1 also highlighted this since her social enterprise facilitates the sales and distribution of paintings by deaf people. She further added that deaf artists are capable of using digital platforms for showcasing their works and selling their products at online marketplaces.

Challenges of using digital interventions by deaf people in Bangladesh

In the previous sections, different challenges of using digital interventions mentioned by deaf people and their family members are highlighted. While those challenges could be related to all sustainability pillars, we found that major challenges are related to health and education services. For example, at the W3_DH1 workshop, one of the participants mentioned that even if health service providers make video relay services available, they will not find sign language interpreters joining the VRS platforms since Bangladesh has a significantly low number of accredited sign language interpreters. The service charge of sign language interpreters is very high, and their engagement will make health services costlier for deaf people. The W3-DH1 workshop participant observed that the use of VRS will therefore be challenging, and the solution to this challenge is to have more health service providers know and use sign language to communicate directly with deaf people face-to-face or online.

A W8_SH2 workshop participant highlighted the same in the context of education services, as he opined that digital skill-building training modules and delivery options do not consider the communication needs of deaf people. Since sign language options are not available, they can never learn like those without impairments and are unable to make themselves competent for the job market. He mentioned that he has been trying to find a job for the last three years without any success. Two participants from the W6_KH2 and W7_SH1 workshops also highlighted that many students from deaf schools drop out when they are supposed to be admitted to colleges after school, since teachers in college do not know sign language. She mentioned that options like video relay services can be used so that deaf students can join the class online with the support of a sign language interpreter at the platform, translating the class lectures for them. However, this participant also acknowledged the unavailability of sign language interpreters in Bangladesh and the implication of using their services on the cost of education.

In addition to the lack of a sign language interpreter, as highlighted before, the lack of consideration to add features like subtitles or sign language video in the main content has been highlighted several times in different workshops like W9_RP1 and W10_RP2. One W9_RP1 workshop participant mentioned that there are animation videos developed in Bangladesh for edutainment and to raise socio-environmental awareness, but producers of those videos hardly consider the entertainment or education needs of deaf people.

A participant in the W3_DH1 workshop highlighted that one of the major challenges of designing digital interventions for deaf people in Bangladesh is the lack of standardised Bangla sign language, considering the variation of sign languages in different geographic locations. She also mentioned that some deaf students were taught through sign language in schools, while some were taught through texts. These two groups have different ways to understand communication, and digital interventions sometimes do not cater to both groups. Interview participant I1_GO1 echoed this concern as he mentioned that embedding sign language in video platforms may not bring the desired results if those are not further customised.

Another participant at the W6_KH2 workshop mentioned that the challenge is less with using the available digital interventions and more with the societal attitude towards persons with disability and deaf people. She highlighted her good skills in using different digital interventions and using those skills at her workplace. However, being a deaf person, she faced misconduct and misbehaviour from her employer and colleagues. Due to the experience, she was forced to leave her job. Based on her experience, she emphasised changing societal attitudes first before focusing on the customisation of digital interventions for deaf people. A participant from the W3_DH1 workshop also hinted at this societal attitude and opined that health service providers do not have a supportive attitude towards deaf people, and the challenge is not entirely related to digital interventions. In this regard, she mentioned:

> Deaf people cannot communicate. If someone writes an email to a doctor about their health issues, I do not think the doctor will spend time reading and understanding it. There is a possibility that the deaf patient will be wrongly treated as a consequence. The doctors are very busy, and there is a high chance that they will deny consultation with a deaf patient.

Another participant from the W5_KH1 workshop also shared a similar experience, as she highlighted that she could hardly get an appointment with a doctor by herself and needed to take support from someone else to get the appointment. The participant opined that the societal attitude is worse about health services in comparison to education services in Bangladesh, which was also indicated by interview participants I6_LN1 and I7_LN2. Moreover, along with the indicated societal attitude, we found at the W1_DP1 workshop that some parents do not think that there is significant usefulness for having access to digital devices by deaf people, as they are sceptical about the ability of their deaf children. The scenario is also applicable in natural disaster-related services, as two W5_KH1 and W6_KH2 workshop participants highlighted that many actors do not acknowledge that deaf people are highly vulnerable due to natural disasters and need customised communication from those actors.

In this regard, interview participant I5_HS1 mentioned that rather than considering the orientation of deaf people on digital interventions, policymakers and key government ministries supposed to serve the persons with disabilities, including deaf people, need to be oriented on disability and the potential of deaf people to change their attitude. She mentioned:

> Those who are responsible for bringing the shift towards digital interventions for deaf people in Bangladesh should be provided with attitudinal change training. Our big guns, like the Ministry of Education and the Ministry of Social Welfare, should be given orientation on disability. Their mental/psychological limitations should be overcome. Digital interventions will progress from their current ground. I never say our deaf people are backward in appreciating digital interventions. They know how to use technology. But the focal points do not know how to provide these services to deaf people.

As we highlighted before, the challenge of low digital access and literacy also came up as a major challenge to using digital interventions in Bangladesh at several workshops. Some participants with a higher poverty headcount ratio highlighted that the use of digital devices, especially smartphones, as well as the use of highly necessary video data by deaf people, is not financially feasible for many families in Bangladesh who are already overburdened due to taking care of their deaf family members who are unable to earn due to socio-economic disadvantages. A participant from the W8_SH2 workshop, therefore, indicated that the low affordability of digital devices is the biggest challenge for deaf people in Bangladesh to utilise digital interventions. In this regard, a participant at the W9_RP1 workshop, who owns a feature phone but cannot afford a smartphone and related data costs, mentioned that deaf people have poor mental health due to not accessing content that can provide them with entertainment. Like that participant, many of them do not have smartphones and are unable to access video content due to their abject poverty. Another participant from the W1_DP1 workshop also highlighted that some parents do not have the literacy to use smartphones, which restricts their ability to provide digital devices for their deaf children. Besides, interview participant I3_DM2 mentioned that many deaf people in Bangladesh are out of 4G internet services and are still living in areas where there is no internet service. For meaningful digital interventions designed for deaf people, this remains a major challenge.

Facilitating the adoption of digital interventions by deaf people in Bangladesh

As the research is concerned with understanding the roles of government and other stakeholders in facilitating the adoption of digital interventions by deaf people in Bangladesh, we found that the roles highlighted by deaf people and their family members are generic for facilitating the digital interventions from the perspective of all sustainability pillars.

According to their opinion, the most important aspect of developing appropriate digital interventions for deaf people in Bangladesh is training and orienting more people on sign language so that they can directly engage in different online activities with deaf people. A W3_DH1 workshop participant in this regard opined:

> Nothing can replace direct communication with a doctor, trainer, or educator. We are happy to interact with others through sign language interpreters. But we also feel that something is missing in the communication.

A W4_DH2 workshop participant mentioned that this can be done by incentivising those who know sign language as an additional language, like any other language. She mentioned that the government has the biggest role to play in this regard by arranging free training programs on sign language. About the facilitation role of the government in providing education services, interview participants I2_DM1 and I7_LN2 opined that the government needs to convert all textbooks into visual forms with sign language, and all delivery lessons also need to be sign language-based so that deaf students do not need to bother about understanding the class lectures if the teachers do not know sign language.

Another participant from the W6_KH2 workshop opined that for some professions like doctors and teachers, the government needs to increasingly make it mandatory for people from those professions to learn sign language as a part of obtaining their qualifications (the same opinion was also expressed by interview participant I6_LN1). Government departments and NGOs need to prefer recruiting staff with sign language skills since their staff have a higher chance of interacting with deaf people face-to-face and online due to their work on different forms of disability. He indicated that to be trained as a sign language interpreter, someone does not need to be highly educated and less educated people can take the opportunity to get the training to become a sign language interpreter. He also mentioned that non-government organisations and business organisations can also play a stronger role in this regard to support orientation programs on sign language.

Another participant at the W3_DH1 workshop mentioned that deaf people are mostly left behind, while digital interventions developed by the government and NGOs for persons with disabilities are targeted mostly towards those having blindness and physical mobility challenges. She indicated that, as the first step to focus on deaf people in developing and delivering existing digital interventions, it should be mandatory to add subtitles and embed sign language videos in different visual content made for education, awareness and entertainment purposes by government departments, NGOs, the entertainment industry and the private sector. In this regard, a W2_DP2 workshop participant opined that sign language interpreters who can speak should be at the centre to make health or disaster awareness-related videos since they can serve the needs of

everyone. Government and other stakeholders in this regard need to engage sign language interpreters to develop their digital content.

Regarding digital access for deaf people, a W8_SH2 workshop participant highlighted that the government should subsidise or provide free digital devices to deaf people while providing necessary orientation, since deaf people will be able to earn income and contribute to society in return. A participant from the W3_DH1 workshop highlighted that having digital access provided him with a lot of opportunities, and he became educated. He is now utilising his educational skills to educate other deaf people while earning. In this regard, he mentioned:

> There were no private tutors for me since private tutors do not know sign language. But I now provide private tuition to other deaf students who want to learn. I have started offering private tuition based on my feelings of deprivation.

Discussion

The findings demonstrate several design problems for our co-design work by using the double diamond design method through initiating the 'develop' phase as the next step. We identified several of the design problems are macro-level design problems. However, our findings also indicate that there are some design problems at the micro-level that human-computer interaction for development (HCI4D) researchers can try to address through future co-development processes. In this section, we are presenting both types of design problems while indicating our approach to address the design problems during the 'develop' and 'deliver' phases.

Perspectives from three sustainability pillars

We acknowledged from the very beginning that although it is important to consider all three sustainability pillars, economic, social, and environmental, for deaf people in Bangladesh to develop any appropriate digital intervention, it would not be feasible for us to aim to co-develop digital interventions related to all three pillars during the 'develop' phase of our design. The 'discover' and 'define' phases provided us with the related insight for prioritisation based on the opinions of deaf people, their family members and diverse stakeholders interviewed. Our findings indicate that health service consideration under the social pillar of sustainability is the most important one for deaf people of Bangladesh from the perspective of developing any digital intervention. Education service consideration was the next important consideration, followed by income generation-related consideration for deaf people. In a couple of locations and from some interviewees, we also found that natural disaster-related service is another notable consideration for deaf people. Since we covered both physical and mental health aspects of health service, we found digital communication initiatives with health service providers, as well as communication on different public health issues, are insufficient for deaf people in Bangladesh. Consequently, the first design problem we want to tackle during the 'develop' phase is framed as:

> Despite its high importance in their life, deaf people in Bangladesh have access to negligible health services-related digital interventions.

Based on this design problem, during the next phase of the design process, our research team has primarily decided to work on digital mental health interventions that could be developed with deaf people through necessary customisation and shared among them with low-cost involvement.

Digital equity

During the first two phases, we identified that while the deaf people as a group face inequality, the group itself is not homogeneous in Bangladesh in terms of digital equity. This is associated with the socio-economic situation of deaf people living in different parts of Bangladesh. Our choice of diverse geographic locations to conduct the workshops allowed us to identify the differences among deaf people in terms of digital literacy. Some deaf people in cities like Dhaka and Sylhet have a strong capacity to use different digital interventions, and they are active in the digital space. They can also afford related costs to access different digital interventions. Their level of knowledge allows them to suggest advanced digital interventions, like sign language recognition applications or innovative digital interventions like video relay services. However, we then identified another group of deaf people who can marginally use a feature phone since they are unable to afford the cost of maintaining a smartphone. They also live at locations where the full advantage of accessing digital content is not possible due to inadequate internet availability. This group of deaf people can only talk about text-based features since the call feature is of no use to them. Finally, we also had deaf people in our workshops who did not have any digital access and possessed no knowledge of digital interventions. While most of them cannot afford any digital technology, some of them do not have access due to family barriers. In Rangpur and Dinajpur, several women participants do not have any digital access, indicating that deaf women in Bangladesh are further marginalised in having digital access. Therefore, considering the overall digital equity situation of deaf people, the second design problem we want to tackle during the 'develop' phase is framed as:

> Due to digital inequity within themselves, deaf people in Bangladesh have varied degrees of capacity to participate in co-developing digital interventions.

Based on this design problem, during the next phase of the design process, our research team will engage deaf young people from urban areas of Bangladesh for co-developing digital mental health interventions due to their mental health challenges, higher digital literacy and access to digital platforms. While some other deaf young people with low digital literacy and access will be excluded from such a co-development process, we will partner with disability organisations, including the relevant government departments, during the 'deliver' phase so that they can non-digitally disseminate the mental health-related content through their grassroots interventions for deaf young people.

Sign language interpretation

As our findings indicate, one of the biggest problems of designing digital interventions in Bangladesh came with an alarmingly low availability of accredited sign language interpreters. The level of availability makes different digital interventions not feasible to implement in the long run if they are fully dependent on the engagement of accredited sign language interpreters. Due to this challenge, participants at the 'discover' phase went up to the point of suggesting that it should be made mandatory for some professionals to learn sign language. There was also a strong emphasis on training more people in sign language and incentivising those who learn sign language. In this regard, for the next phase of design, we identified that it is out of our design scope to push others to learn sign language, to train others on sign language, or to incentivise others who learn sign language. However, we can broaden our options by innovatively utilising the

sign language skills of deaf people themselves and their caregivers. Besides, we also observed different digital interventions done by other entities by engaging accredited sign language interpreters while using mass media to share the outputs widely.

One such example is provided in Figure 5 below, where one of the leading sign language interpreters offered her service to produce videos on different topics by using sign language videos. The related costs to produce such content were borne by the biggest telecommunication company in Bangladesh. Another example in Figure 6 below shows another video that was developed by one of the largest disability organisations in Bangladesh by using their staff and volunteers who are sign language interpreters without hearing and speech impairments, as well as some deaf people, since the main target of the video was to orient others on sign language by using background voice and Bangla text. These initiatives indicate that when investment and willingness from key stakeholders, including the private sector, NGOs, and government, are there, engagement of sign language interpreters could be managed to a certain extent. This will also incentivise others to learn the language since they will observe an earning opportunity by becoming a sign language interpreter. Keeping this in mind, we therefore frame our third design problem as:

> Engaging sign language interpreters is highly essential in developing digital interventions for deaf people in Bangladesh, while the high costs of their engagement need to be sustainably managed at the initial stage to ensure lowering the costs at a later stage.

Figure 5: A corporate-financed orientation video on different terms in sign language by engaging an accredited Bangla sign language interpreter, accompanied by Bangla and English texts. [Public domain], via YouTube. (https://www.youtube.com/watch?v=z08yRPKmrHk)

Figure 6: An NGO-financed orientation video on different terms in sign language by engaging a Bangla sign language interpreter, accompanied by Bangla texts and voice. [Public domain], via YouTube. (https://www.youtube.com/watch?v=B9WqJbzp020)

Considering this design problem related to engaging sign language interpreters and associated cost, during the next phase of the design process, our research team will therefore engage deaf people and their caregivers in developing some digital interventions on an experimental basis through providing necessary orientation so that the development of digital interventions does not remain fully dependent on sign language interpreters.

The digital intervention and platform

From the discussions during the workshop and interview, as well as by reviewing related academic works, we understood that in the current context of Bangladesh, we need to focus on digital interventions that are not costly to co-develop and deliver, as well as can be widely shared in digital platforms that are mostly used by deaf people. In this regard, some of the digital interventions, like sign language recognition applications, need strong technical skills to develop, and their co-development process cannot guarantee the participation of deaf people and some stakeholders due to their lack of related knowledge. In contrast, we found that along with developing audio-visual content, many other available audio-visual contents only need to be made accessible for deaf people by adding subtitles and embedding sign language videos that are shareable in their preferred digital platforms like WhatsApp, Facebook, Imo, etc., without costing them highly to access and share. However, we also need to acknowledge the fact that many deaf people do not have smartphones and can only receive and share text. They do not have a choice of digital platforms in this regard. Besides, those without digital access also need to be considered in designing digital interventions so that there is a social arrangement and support for them to access digital content from others. Considering all of these factors, our fourth design problem is framed as:

> Digital interventions and digital platforms are not equally affordable, accessible, and understandable by all deaf people in Bangladesh, where non-digital interventions and platforms are frequently used to ensure inclusive development.

We will follow a similar approach to the second design problem in addressing this fourth design problem while moving forward during the next phases of co-design. We will engage digitally literate deaf young people capable of accessing digital platforms and producing digital content that requires low technical skills. We will then facilitate the dissemination of materials of digital interventions non-digitally for those with low digital literacy and access during the ‘deliver’ phase.

The societal attitude

The last major challenge of co-developing digital interventions with deaf people in Bangladesh has been identified as a negative societal attitude towards people with disability in general, and deaf people in particular. Important social actors, including family members of deaf people, sometimes demonstrate scepticism regarding the capacities of deaf people to use digital interventions. Some key professionals, like doctors and educators who are supposed to provide key social services like health and education, are not empathetic enough towards deaf people, while their participation is extremely important to make any related digital intervention successful. As this problem is also at the macro level and may seem beyond the scope of our co-design process, there is also an opportunity to engage a group of champions, like a group of health professionals, whose participation can influence changing societal attitudes. Considering this, our last design problem is framed as:

> Lack of societal empathy towards deaf people in Bangladesh on the part of key stakeholders is a major barrier to co-developing digital interventions by engaging those stakeholders.

As our research team has primarily decided to work on digital mental health interventions during the next phase of the design process, to address this design problem, we would engage mental health professionals like psychiatrists and mental health advocates during the co-development process in our effort to create empathy towards deaf people.

Conclusion and way forward

Our goal in this paper has been to present the complexities of co-designing digital interventions for deaf people, an extremely socio-economically marginalised and environmentally vulnerable group, in a developing country like Bangladesh, where the Government has been pursuing an ambitious development vision based on digital advancements. Our research utilised the double diamond design method, and the paper presents the findings and insights of the first two phases of the design method that are guiding us to initiate the next two phases of the design based on identified design problems and practical realities of co-designing digital interventions with deaf people in Bangladesh. In the discussion section, we have highlighted several design considerations for the next two phases based on design problems highlighted in this study, when our research team is going to initiate a co-design process on deaf young people in urban areas of Bangladesh on digital mental health interventions.

In this study, we took a holistic socio-economic and socio-ecological approach during the 'discover' phase of our design by considering the social, economic and environmental dimensions of sustainability for the advancement of any entity, including the human being. Our findings demonstrated a way to interpret the opinions of deaf people, their family members and stakeholders while acknowledging the diversity of their opinions. We also indicated our findings logically by structuring the insights from workshops and interviews through discussion on options, needs, capacities, challenges, and facilitation roles concerning digital interventions for deaf people in Bangladesh from the perspective of sustainability pillars.

The study is limited due to its focus on the first two phases of the double diamond design method, while we acknowledge the usefulness of sharing the insights and design problems of those two phases for making the right human-centric design choices during subsequent phases. However, we have pointed out how we are planning to incorporate the findings of the first two phases for the 'develop' and 'deliver' phases, when there will be a specific focus on a particular topic related to one of the sustainability pillars (i.e., mental health) while engagement will be established with a particular group from the deaf community in Bangladesh.

Due to the use of sign language interpreters as a mediator to gather information and transcribe information from video, we also acknowledge that data was lost in translation, which can be avoided when information is audio-recorded and a verbatim transcription can be ensured. However, that provided us with a scope to rethink our research approach in conducting research with deaf people.

In moving forward, considering some of the macro-level design problems, when we will act on the design problems to suggest a set of design considerations related to one aspect of the triple bottom line for co-developing and delivering digital interventions for deaf people in Bangladesh, we will have a strong emphasis on influencing the government and other stakeholders for sustainable scale-up by partnering with disability organizations in Bangladesh.

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