THE VISIMP PORTABLE COMMUNICATIONS DEVICE FOR VISUALLY IMPAIRED INDIVIDUALS – DEVELOPMENT AND FEASIBILITY STUDY OF AN ASSISTIVE TECHNOLOGY

M.B. Garcia[1] and N.U. Pilueta[2]

[1]College of Computer Studies, [2]College of Engineering
[1][2]FEU Institute of Technology
Manila, Philippines.

Corresponding Author's Email: [1]mbgarcia@feutech.edu.ph

ABSTRACT: From undesirable health outcomes and poor quality of life to restricted self-care activities and communication barriers, visual impairment is a disorder that needs to be addressed. Like any other medical condition, it is potential beneficiary of a technology-based solution to compensate, at least in part, for the given functional limitations. In recognition of the complex challenges brought by visual impairment, this study proposed to develop a communication device called VISIMP, and explore its feasibility with the aid of three visually impaired people (with one selected family member each), and two healthcare professionals in a 4-week feasibility study. By utilizing a mixed-method study approach, both quantitative and qualitative data were collected via an informal interview, task performance, and survey based on the factors influencing assistive technology adoption. VISIMP development lifecycle is also grounded on a framework for building assistive technology. After a series of testing and evaluation, study participants labelled VISIMP communications device as a promising assistive technology that poses great potential to support visually impaired individuals in their day-to-day lives.

KEYWORDS: *Portable Device, Communications Device, Visual Impairment, Assistive Technology, Feasibility Study*

1.0   INTRODUCTION

Among the modalities of sensory systems, human vision is reflected as the most influential sensory function [1] where communication and perception are interconnected brought together by the human brain. Consequently, visual-perceptual deficit significantly affects the ability of individuals to enable and perform social interaction [2]. According

to World Health Organization (WHO) [3], it is projected that about 1.3 billion people have some form of visual impairment (e.g., blindness, low visual acuity, strabismus, cataract, glaucoma, age-related macular degeneration). Nevertheless, much research has been focused on the impact of vision loss in order to understand the overwhelming and terrifying struggles of those affected. For instance, visual impairment is associated with poor quality of life and numerous negative health outcomes [4, 5] particularly when the underlying eye disease affects peripheral vision [6]. Moreover, the loss of vision troubles numerous casual activities such as reading, socializing, and pursuing hobbies, as well as basic self-care activities of daily living such as bathing, eating and dressing [7, 8]. As a result, individuals with vision impairment requires long-term care especially when mobility is greatly affected [9, 10] (for instance, walking or going up or down steps [11]). It is the reason why there is actually a prevalence of fall [12, 13], fracture [14-16], and other subsequent injury [17-19] among people with visual impairment. Furthermore, mental health is also greatly affected due to high risks of depression, anxiety, and other psychological problems [20] as compared to people with normal vision. Several studies have also found the connection between cognitive and visual impairment where the former is more progressive when the latter is existing [21-26]. Finally, there is also a greater mortality and morbidity in visually impaired people caused by accidents, falls, and other injuries [27-30].

In recognition of the complex challenges faced by visually impaired individuals, various intervention approaches have been proposed in many parts of the world to allow communication between people and across environments. Parker and Ivy [31] penned a brief synthesis of intervention research for visual impairment and deafblindness, and grouped various practices into different clusters such as technological supports, training programs, wait time, adapted pre-linguistic milieu training, Picture Exchange Communication System interventions, and literacy- or narrative-based approach. In the education sector, these communication interventions are equally communal for students with disabilities. For instance, the case study coordinated by Kharade and Peese [32] in e-learning tools and application exposed the accessibility challenges, usability limitations, and insufficient traditional adoption factors [33]. Certainly, corrective measures should be executed on the problematic features of online educational tool for people with visual impairment. Assistive technologies (e.g., academic tools such as sign language recognition [34], screen readers, magnification devices [35]) are also getting efficacious in meeting the demands of the challenging mainstream settings of traditional classroom environments. Likewise,

the educational intervention orchestrated by Rabello et al. [36] aided participants to improve their reading skills after utilizing an assistive technology device. Further, there was also a computer-based reading comprehension assessment tool [37] albeit there were no significant difference in reading comprehension when compared with paper-based assessment. In science courses, three-dimensional models of human bodies and organs for anatomy lessons are used by teachers to discuss topic or impart knowledge. Students with visual impairment made significant improvements and projected high level of interest towards the use of haptic technology and tactile models of the cell as instructional tools [38]. Drawing interpretation from the literature, it has become essential to integrate assistive technologies, regardless of the type and technique, into students' ideal functional activities [39, 40] as reinforcers of enabling increased change of success [41, 42].
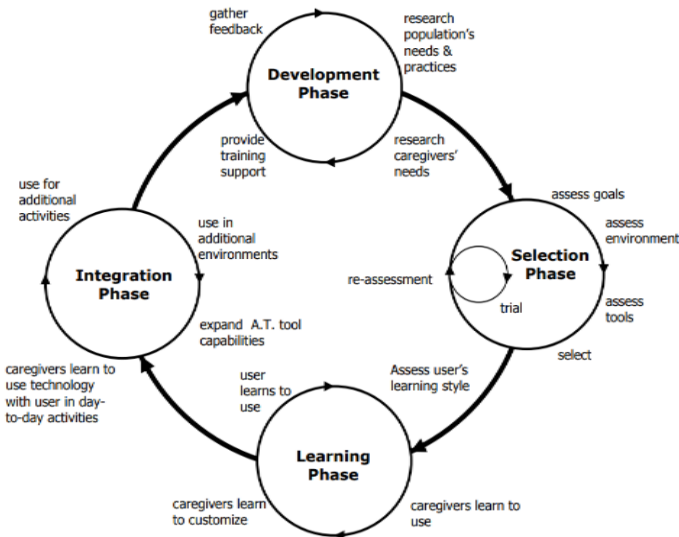

Figure 1: Framework for Developing Assistive Technology

In this paper, the development and feasibility analysis of a portable communications device called VISIMP were described. The main goal of VISIMP is to provide a visually-impaired-ready-device to facilitate communication with other people, visually impaired or not. Through the course of the study, VISIMP was tested by three visually impaired people (with one selected family member each), and two healthcare professionals in a 4-week feasibility study utilizing a mixed-method approach. Quantitative data were collected via a survey based on the factors influencing technology adoption of visually-impaired people [43] and individual task performance for testing each VISIMP module (e.g., location tracking, receiving and sending calls and texts, speech

output module from scanned documents and received messages, and text extraction from scanned document) while qualitative data were retrieved using informal interviews. Illustrated on Figure 1, the device development of VISIMP is strictly grounded on the framework for the adoption of assistive technology [44]. With VISIMP device, this paper also intends to realize if there is something we could do to contribute in the betterment of day-to-day lives of visually impaired individuals.

2.0   METHODS

In software development, the utilization of prototyping methodology is employed when users must be part of the development process and a throwaway prototype, that is, an initial approximation of the final product is needed. Such model is used in developmental projects when it is challenging to obtain exact requirements, hence, the involvement of users for early testing and constant feedback delivery. Aside from using a prototyping model as a basis of the project development of VISIMIP, a framework for building assistive technology was also employed. Kintsch and DePaula [44] built this framework to facilitate a successful adoption of assistive technology tools by disabled people. Much like prototyping model, this framework targets the involvement of users as participants of the adoption process such as caregivers, assistive technology specialists, designers, and developers to bring certain attributes to the table. For the succeeding subsections of the paper, each discussion was deliberately aligned on the adoption cycle phases of assistive technology framework.

2.1   Concept Evaluation of Communications Device for VI

Before any VISIMP device prototype was created, potential users and experts such as visually impaired individuals, hardware and software developers, computer engineers, and healthcare professionals were all invited to participate in an informal interview to draw a preliminary baseline of their perception towards such communications device. All interviews were transcribed, and then analyzed for later usage to aid the quantitative feedback. In addition, existing literature related to the study was reviewed to support the qualitative data supplied by users. Visual impairment, device hardware, portable device design, assistive technology, communication strategies to use with visually impaired people, and other computing concepts were some of the search terms used in building the concept of this paper. Based from the feedback of users and the results of literature review, the prototype development phase oF VISIMP Communications Device was commenced.

2.2 Prototype Development of VISIMP Assistive Device

The VISIMP device prototype was produced one week following the concept evaluation. At this point, a number of high-fidelity prototype were drawn to encourage more evaluations and feedback from users. The primary goal of high-fidelity prototype development prior to the construction of the actual device (hardware and software) is to invite insights and criticisms in order to determine potential problems in the early process stage of gathering requirements and analysis. Moreover, tacit or implicit knowledge (which are inaccessible by other methods) is likely to emerge with prototypes since it gives users some hints of what is possible with the project and how the final product should be designed, which then provide a starting point for discussion.
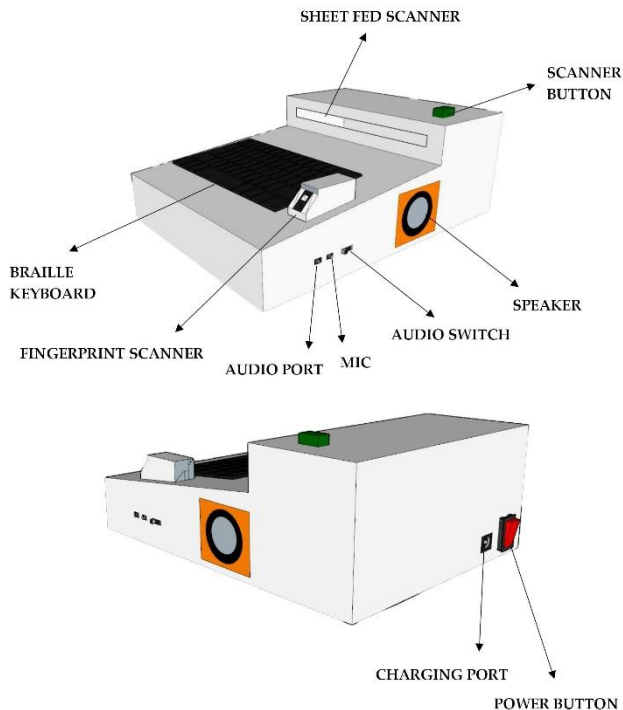

Figure 2: Prototype Design of VISIMP Communications Device

2.3 Development of VISIMP Communications Device

The proposed communications device entitled VISIMP was designed to offer an assistive technology for visually impaired individuals. To do so, a number of hardware components must be integrated with one another to achieve the proposed goal of the study. The following materials were used in this study: A4 Tech HS-5P, GSM (Sim 800), Fingerprint Scanner, GPS (GR-89), Portable Scanner, Jared USB Mini

Speaker, LM2596, Sound Card, Bluetooth Keyboard, Battery 7.4, USB to TTL, and a compute stick. With these components, the hardware system was built to match the capabilities of the software system.
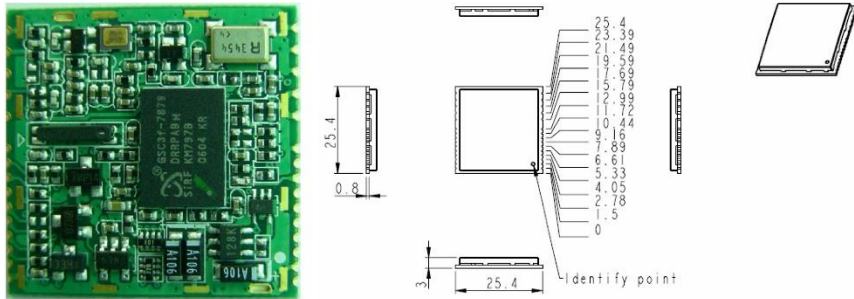

Figure 3: GPS Receiver Module and Mechanical Dimension

Modules of VISIMP device are (1) the processing module that acts as the operating system, (2) fingerprint module for user verification, (3) Optical Character Recognition module for scanning the document and convert it into digitized text, (4) GPS module for the location tracking, (5) GSM module for receiving and sending calls, (6) a text-to-speech module, and (7) inbuilt calculator software mode for performing basic arithmetic. Figure 4 illustrates the schematic diagram of VISIMP when hardware components are combined together to work as one.
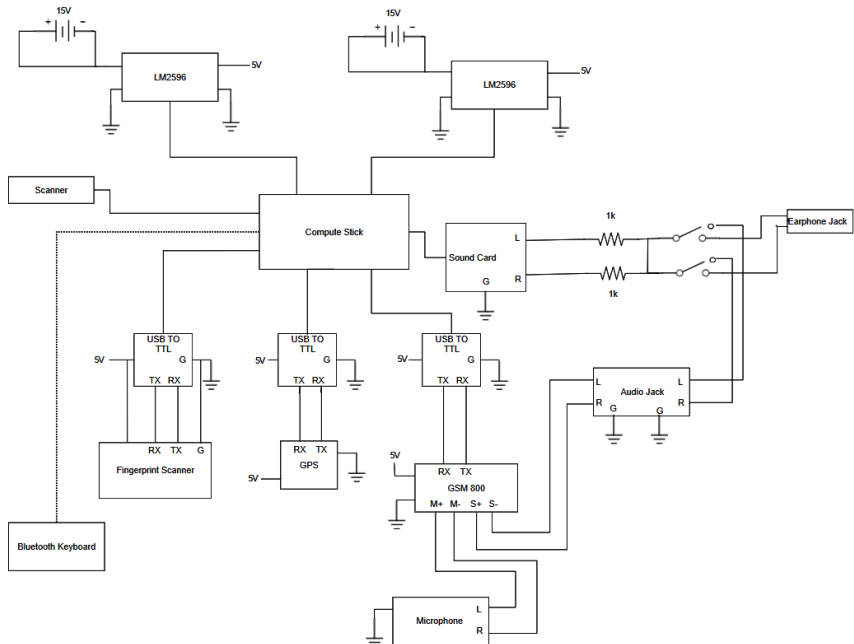

Figure 4: Schematic Diagram of VISIMP

Figure 5: The VISIMP Portable Communications Device for
Visually Impaired Individuals

2.4 Evaluation of VISIMP Communications Device

After six months of device development, the final version of VISIMP
(see Figure 5) was evaluated by three visually impaired people (with
one family member each), and two healthcare professionals in a four-
week feasibility study. It is important to note that a testing stage was
accomplished together with software developers, computer engineers,
and other technology experts prior to transitioning the VISIMP device
evaluation to potential users. The feasibility study is a mixed-method
design intended to gather quantitative and qualitative feedback of the
users. During the first week of the feasibility study, the focus of users
as participants was on the communications module by receiving and
sending calls and texts to their family members, and vice versa. The
succeeding weeks concentrated on other modules that they could use
within VISIMIP. Afterwards, they completed a survey questionnaire
on their experiences, which included a quantitative instrument, and
closed and open-ended questions. The study was approved by the
Ethical Committee of the institution, and strictly in accordance with the
ethical principles of the World Medical Association Declaration of
Helsinki. Moreover, informed consent for participation was likewise
obtained from all individual participants included in the study. Both
online and offline evaluations were conducted, whereas a google form
was created for online evaluation and a paper handout equivalent to
the content of online version was given after the feasibility study.

3.0   RESULTS AND DISCUSSIONS

The primary goal of VISIMP is to develop a visually-impaired-ready-device to enable communication with other people, visually impaired or not. However, a communications device like VISIMP was not new to the health professionals (N=2) unlike the visually impaired people (N=3) and their relatives (N=3) who are only familiar with the use of smartphones. Health professionals noted that "*most of doctors in our field of specialization are already accustomed to devices like OwnFone Braille phone*" [PHC1] and the "*use of such device has been a seasonal topic with patients during consultations*" [PHC2]. Nevertheless, participants (6/8, 75%) were enthusiastic about the VISIMP communications device although they were a bit skeptical and concerned with the cost (5/8, 63%) of such device. Furthermore, participants stressed out that the "*device must stay away from existing phones and must provide functionality that is not available on smartphones*" [PVI1, PVI3, PCE1, PSD1]. Finally, VISIMP communications device must also be secured (8/8, 100%), not cost too much time to learn (6/8, 75%), and budget (6/8, 75%). Excerpts of the feedback of participants are listed on Table 1.

Table 1: Summarized Quotations from the Informal Interviews

Theme	Quotations
Cost	A communications device like this must be expensive when released on the market since there seems to be so many features and hardware, though I still think that a smartphone can perform those things too. [PF1] The schematic diagram is well-designed although the developers can reduce the cost by opting out with less expensive hardware. [PCE1]
Security	An important thing for me in a communications device is the security of my data especially when it comes to medical information. [PHC2] I am not worried sharing my location in the device because it can help my family to find me when something bad happens to me. [PVI1]
Appreciation	For disabled people like me, I appreciate it so much when people create things for us. It's been difficult to express our thoughts and communicate with people because of barriers brought by disability. [PVI2] It has been difficult for me to see my son experience such challenges in life and any gadget or technology that can help him through those challenges are always welcome. I truly appreciate the fact that there are still people who do not forget other people like my son and think about how to help them go with their everyday life. [PF3]
Familiarity	I am familiar with other device for blind people, and this device should offer more innovative features to beat them. [PHC1] We are already using mobile phones to communicate. If this device will introduce new features, then I think my son will likely use this. [PF3]
Features	I like this device. However, I think it is still too big and not portable enough compared with phones. It would be hard to bring this anywhere. Plus, I am not sure how to use this without the battery charging. [PVI3] The readiness of text-to-speech conversion is a very helpful tool for people with visual impairment like blindness. [PHC2]

For communications performance, the VISIMP device was evaluated and received an average of 4.8 (on a scale of 1 to 5), 4.2 for the optical character recognition, 3.9 for the tracking of users' location, 4.9 for text-to-speech conversion, and 3.8 for fingerprint verification. Overall, VISIMP communications device was scored as 4.89 (Excellent) though the qualitative feedback showed mixed reactions. Some participants believed that features of VISIMP are already present on smartphones. Then, those who are acquainted with other communications device related to VISIMP believed that a new device version aiming to cater visual impairment should offer new features to beat the existing ones on the market. There are also comments on the hardware system from the technology experts that must be addressed in the future if in case the VISIMP would be further improved and enhanced. On table 2, the task performance was recorded to track the development progress.

Table 2: Task Performance by Study Participants

Methods	Trials							
Did VISIMP open the message inbox?	1	2	3	4	5	6	7	8
Did VISIMP write text message?	×	✓	×	✓	✓	✓	✓	✓
Did VISIMP receive and send text/calls?	×	×	×	×	✓	✓	✓	✓
Did VISIMP scan properly the document?	×	×	×	×	×	×	×	✓
Did VISIMP perform basic arithmetic operations?	×	×	×	×	✓	✓	✓	✓
Did VISIMP locate the prototype?	✓	✓	✓	✓	✓	✓	✓	✓
Did VISIMP save contact information?	×	×	×	×	×	✓	✓	✓
Did VISIMP check the contact list?	✓	✓	✓	✓	✓	✓	✓	✓
Did VISIMP make speech output?	✓	✓	✓	✓	✓	✓	✓	✓
Did VISIMP authenticate user's biometrics?	×	×	×	×	✓	✓	✓	✓
Did VISIMP provide time and date to the user?	×	×	✓	✓	✓	✓	✓	✓
Did VISIMP change the time and date settings?	✓	✓	✓	✓	✓	✓	✓	✓
Did VISIMP replace the saved biometrics data?	×	✓	✓	✓	✓	✓	✓	✓
Success Rate (%)	31	54	54	62	85	92	92	100

Aside from task performance and informal interviews, a survey based on factors influencing assistive technology adoption of people with disability [43] was also conducted. The result is shown on Table 3.

Table 3: Task Performance by Study Participants

Domain	Factors	Mean	SD	Interpretation
Physical design of technology	System Security	4.32	.53	Excellent
	Convenience	4.31	.67	Excellent
	User-friendliness	4.02	.32	Good
Social Context	Social Acceptance	4.33	.21	Excellent
	Cooperation	4.09	.29	Good
Psychological	Reliability	3.95	.63	Good
	Ease of Use	3.92	.49	Good
	Safety	4.69	.23	Excellent
	Usefulness	4.74	.12	Excellent

Overall, this developmental-feasibility paper explored how potential users such as visually impaired people, their relatives, and healthcare professionals experienced VISIMP communications device. The main concerns emerged from closed and open-ended questions revolved around four interrelated concepts: portability, security, features, and smartphone comparison. At first, participants were pointing out the similarities of VISIMP to a regular smartphone. It was then explained that the goal of VISIMP is to produce a user-friendly communications device that could cater visually impaired people. This is supported by features being offered by VISIMP. Although, participants were asking for added features that might enhance the device such as music and built-in brail keyboard. On the other hand, family members were most excited about the location tracking which could potentially save their loved ones from danger, or from getting lost. When it comes to security, participants were assured that their data is secured, and that any data processing concerning their information needs consent from them. Lastly, portability was pointed out as well particularly on the size of VISIMP that should have a size similar to a mobile phone. All of participants' opinions were considered for revisions.

4.0   CONCLUSION

The VISIMP communications device provides a fresh new perspective at how technology could deliver visually impaired people the tools (e.g., assistive device) they need to thrive despite of barriers brought by their disability. Albeit VISIMP requires revisions especially on portability and features, there were also some good points that made participants excited and appreciative. For instance, VISIMP's built-in location tracker notifies the immediate family members and relatives about the real-time location of their visually impaired loved ones. Communication is also part of the advantage of VISIMP since the traditional applications of assistive technology in visual impairment are mobility, navigation, and object recognition (i.e., obstacles).

Nevertheless, the findings of this study should be carefully weighed considering there were a few potential limitations of methods. First, because the study scope was restricted to the general impression of visual impairment, some forms of vision loss (e.g., blindness, cataract, glaucoma, etc.) may not enjoy the benefits of nor need VISIMP. For example, a person with Hemianopsia could still use smartphones without special features projected for visually impaired. On the other hand, blind people might require more specialized features focusing on mobility support. Further, only eight participants were recruited for

the study since it is difficult to find visually impaired and health professionals who are willing to participate in such study. Therefore, finding of this study is not yet generalizable. Lastly, the assessment of VISIMP was merely to establish the feasibility of the device.

Future research works of similar study caliber must focus on assistive technology solutions (e.g., gamification [45]) to not only make the quality of life improved but also provide a social or economic impact. Furthermore, fundamental challenges of visually impaired must also be addressed head-on in a cost-effective manner as asserted by the study participants. To do so, technologists must understand first the nature, scope, complexity, and diversity of challenges in order to come up with a more effective and efficient solution. After all, people with disabilities are humans too, and they deserve to live the way in which normal people do. VISIMP is a voice that empowers the goal of stirring the world towards a fully inclusive society where people, disabled or not, could enjoy each other for who they truly are without solitude, judgment, hindrance, exclusion, inferiority, heartaches, and loss.

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