Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 41 Issue: 12-2022
DOI 10.17605/OSF.IO/JSUYB

TRAFFIC LIGHT ISSUES FOR VISUALLY IMPAIRED PEOPLE

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Abstract

Eyesight is the most significant sense of all human senses, and it is essential for comprehending our surroundings. However, millions of individuals around the world suffer from visual impairment. A lot of work has been done to solve the problem of visually impaired people. But all of these have ignored the user's genuine requirements. This project has chosen to address a problem that affects the visually impaired. Crossing a road; or, to be more precise: Recognition of Pedestrian Traffic Lights. First, we tried to uncover the challenges and needs that visually impaired people face when crossing a signalized intersection in order to explain the supporting system for them to cross safely at a signalized intersection. A literature review was conducted, the existing techniques provided in them were reviewed and a critical analysis was given by combining them into a table. Well, we have suggested a talking cap as a solution for the visually impaired to understand the traffic lights. A camera will be embeded on the top of cap that will take an image of the current situation. It will just scan the traffic lights, identify the color and give the output through voice in earphones. And user can hold a simple stick just for its stability and balance support. In which the output will be given through voice. And its effectiveness was evaluated by experimenting in the school. Three usability parameters were then used for analysis and we found a very good user experience for effectiveness, efficiency, and satisfaction. Overall scores are recorded as effectiveness is 87.50%, efficiency is 87.01%, and satisfaction results are 82%. This research could have an important impact on resolving VIs issues because it provides guidelines and strategies for developing a user-friendly, user-interactive design and open new doors for the researcher to invent something different which can meet the actual requirements of a user.

Keywords: Visually Impairment, VIBs, Detection, Recognition, Traffic Intersections, Pedestrians.

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1. INTRODUCTION

Our eye functions similarly to a camera collecting, focusing, and transmitting light through a lens to form images of our own surroundings. In our daily lives, vision is crucial. However, according to the assessment of WHO (World Health Organization). In 2017, Out of 253 VI people, 36 million are blind and the other 217 million are suffering from partial vision loss problems [1]. And over 2.2 billion individuals worldwide suffered from vision impairment in 2019. Furthermore, the bulk of these visually impaired individuals is above 50 years old [2]. In developing countries, about 0.4% of the population is blind, whereas, in underdeveloped ones, it might reach 1% [3]. Vision loss has a huge influence on the life of people, including their potential to tackle and understand their surroundings on their own [4].

Unlike persons with normal eyesight, these persons are unable to see the items around them. When traveling, they have difficulty identifying impediments [5]. Obstacles, congestion, noise, and complicated layouts navigating difficult for such a group of people [6]. Due to their diminished sense of their surroundings, the visually handicapped have a difficult time leading an independent life. When visually impaired people engage with their surroundings they experience two major challenges. The first is to detect and recognize the objects in their immediate environment. This is referred to as the identifying problem. Second, the present location must be determined in relation to the destination and route. This is referred to as the navigation issue [7].

Visual impairment, on the other hand, can affect people in their products or even pre-productive years owing to a congenital flaw, an illness, or an injury. In such circumstances, the disability has an enormously greater impact on the disabled's life. Vision loss significantly impairs one's capacity to locate in both known and unknown settings, compared to impairment in any other human sense [8]. For several persons, especially those that are visually impaired, transport safety can be a big concern. They may observe themselves in extremely unsafe conditions if they become distracted and do not receive assistance [9]. Mobility plays a significant role in all human lives. It is vital for safety to be able in seeing, hearing, and experience the context of the environment. To navigate, visually handicapped depend on their forethoughts of an environment, with the assistance of a guide dog or white cane. This makes it difficult for them to achieve the appropriate amount of mobility and context awareness, particularly in unfamiliar surroundings. The majority of these systems are significantly reliant on the underlying infrastructure, which limits their use in areas where the infrastructure is unavailable. A limitation of contextual information offered to the user is another disadvantage of existing navigation systems [10].

According to the report Inegalit'e des Chances'("Inequality of Opportunities"), a national study conducted by the Canadian National Institute for the Blind between 2003 and 2005, at minimum 50% of visually impaired persons need help in their everyday lives [11]. With the growing number of visually challenged people, the need for a navigation and orientation solution has grown as well. The goal is to inform researchers interested in contributing to this subject on the current state of the problem. This document gives a summary of the work done for visually impaired persons, covering what work has been done for them so far, what devices have been produced for them, and what are the benefits and limits of those technologies [12].

In view of all these problems of the blind, my research aims to develop a prototype that allows visually impaired people to easily understand traffic signals and cross the road. The development of new automatic technologies to aid people with visual impairments is necessitated [13]. To fulfill this specific goal, the rest of my work is categorized into the following sections. In section 2, a literature review of several other scholars is mentioned and the research methodology is presented in section 3. The results of usability factors are discussed in section 4. Finally, in section 5, the overall work is summarized.

2. LITERATURE REVIEW

Wan-Jung Chang et al. [2] proposed an AI edge computing-based wearable assistive system to assist visually impaired persons in safely crossing a marked crosswalk. This system is made up of a pair of smart sunglasses, a waist-mounted intelligent device, and an intelligent walking stick. For real-time zebra crossing AI-based deep learning technique is used. While approaching a zebra crossing, the visually impaired wear smart sunglasses, and a waist-mounted intelligent device and hold a proposed intelligent walking stick. When a visually impaired person reaches a marked crosswalk he will receive an immediate message informing him of the present condition at the crossing as well as traffic light signals. As a result, the proposed system can help to meet the goal of improving pedestrian safety while crossing intersections.

Manjari et al. [12] Conducted a review of previous work on VIs. Researchers attempted to discuss the beneficial technologies designed for the VIs, focusing on their operation, utility, and characteristics. And compared the devices based on numerous characteristics to make it more exciting and clear. Xiang Li et al. [14] developed an innovative and effective technique named Cross-Safe that gives accessible as well as appropriate guidance to the VIs as one crosses junctions. It is begun by concentrating on the red-light-green-light, go-no-go conundrum. Cross-Safe used cutting-edge deep learning techniques to identify and recognize pedestrian signals in real time. More precisely, for Cross Safe, a lightweight identification algorithm was created and integrated, allowing for reliable walking signal sign detection. Vocal assistance transmitted recognized signals to VI end-users, which gave vital information for real-time intersection navigation. This technique was tested and validated by developing a custom image library on real traffic intersection.

Employing a smart stereo vision sensor named OAK-D and edge AI devices, Jagadish K. Mahendran et al. [15] developed an innovative and practical architecture for a visual

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aid system that can overcome the limits of previous systems by using edge AI technology. Using state-of-the-art computer vision and deep learning methods, the system has been designed to perform sophisticated scene understanding tasks such as detecting roads, curb entry/exit locations, pedestrian crossings, assessing traffic conditions by detecting traffic lights and congestion, and reading traffic signs and street names. The suggested system can detect elevation changes at entrance/exit points using 3D point cloud analysis. Interviews with visually impaired persons, including those from non-profit groups like Lighthouse for the Blind Inc., were undertaken in order to better understand and catalogue the obstacles they experience on a daily basis. Based on these interviews, the authors prioritised and rated the identified concerns, and solved them in their design.

Zhu et al. [5] built a virtual guiding robotic environment and a physical prototype for VI people using the fog computing model in which Phone + Embedded board + Neural compute stick are included. The phone, embedded board, and neural compute stick work together to produce a great fog computing platform that meets the requirements of real-time video / audio processing. Multiple decentralized services and devices have been effectively integrated using a visual programming environment in this research paper.

Bauer et al. [16] Offered a system that can convey the location of probable barriers in outdoor scenarios. The strategy of that system is built on non-intrusive wearable technologies that are also inexpensive. Firstly, a depth map of the scene is calculated from a color image, providing 3D information about the surroundings. The semantics of the things in the scene are then detected by an urban object detector. Finally, the 3D and meaningful data are condensed into a more clear representation of the probable impediments that users may face. The user receives this information in the form of verbal or haptic feedback.

Aiordchioae et al. [17] proposed a set of smart glasses-based assistive applications for VI people. For this purpose firstly they analyzed 13 smart glasses prototypes by studying 500 scholarly papers and a survey of commercial smart glasses to achieve this goal. Omar Gamal et al. [18] proposed a learning-based outdoor navigation system to aid VI people in maintaining their independence. The method is based on two different navigation strategies: macro- and micro-navigation. In macro-navigation, the Google Maps app on a smartphone is used to plan a route from the current location to the destination address, whereas, in micro-navigation, CNN networks are used to ensure the safety of the visually impaired person while navigating on the sidewalk and maintain a straight course all the way to the destination address. The technology employs voice feedback to give the visually impaired person helpful directions.

N. Prakash et al. [19] Offered a camera-based system for detecting the object of interest while the blind user just captures it for a few seconds. To identify the product, the photos are first saved in a database and then recognized using MATLAB software. The image processing in MATLAB is done with the image capture toolbox, and the MATLAB output is sent to the processor. The Raspberry Pi, which is based on IOTs, is used to interface with MATLAB software. It compares the image to previously saved database photographs in order to identify a certain product or person. The image is captured with a web camera, and the image is processed such that the name of the person or product is created as a speech output to blind people through an earphone.

Chikadibia and Rym Z. [20] presented a cloud-based IoT edge computing system. A solution for visually impaired people. This proposed system provides VIB persons with a highly available, scalable, highspeed and low-latency traffic light notification. It is composed of three main equipment: a smartphone with detect signal App. This app is working on GPS-enabled phones and is used to send notifications that notify the VIB that are near to traffic light. The second is a low-cost IOT device that is mounted on traffic lights and the third is a cloud platform. Nguyen et al. [21] proposed a prototype enabling colorblind people to imitate the same experience as people who are not colorblind. Three use scenarios, such as traffic lights, fruit colour distinction, and graph reading in a virtual conference room, are used to demonstrate the proposed prototype. The proposed strategy can increase colour differentiation and accuracy for colour blind people, according to a pilot study with 29 participants.

Rahul Johari et al. [22] presented a smart stick that is based on a TLC (traffic light cross-ing) algorithm for visually impaired people can use for navigation and guidance while nav-igating through streets and crossing traffic signals. This smart stick contains an ultrasonic sensor for detecting obstacles, a colour sensor for detecting traffic light colour, a buzzer and GSM-based SMS alert system. This cane is equipped with GPS navigation as well as a speech recognition system. Castillo-Cara et al. [23] Introduced a mobility aid prototype for visually impaired people. Its design is based on an AVR microcontroller. For communication interfaces, Bluetooth 4.0 devices were adopted.

The mobile assistant was created with the necessity for a low-cost solution in mind in the setting of Latin American cities. Iqbal et al. [24] developed an application that recognises various forms of colour blindness and switches to the appropriate colour mode automatically.

3. METHODOLOGY

In this paper, a UCD process model as shown in Figure 1 is used to design and validate the prototype. UCD process model is composed of following steps (i) identifying the problem (ii) define the context of user (iii) specify requirements (iv) design solution (v) experiments (vi) analysis [25].

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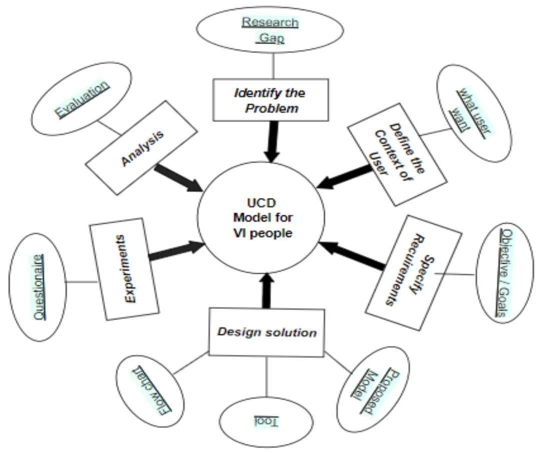

Figure 1: UCD Process Model.

Identify the Problem

The first step in UCD process model is to identify the problem in the existing assistive tools. The most common assistive tools white canes and guide dogs are used for the help of visually impaired people. But in term of performance, these are not enough to fulfill the needs of Vis people. These tools are limited because of their speediness, capabilities and coverage.

Define the Context of User

As we are talking about the users who are visually impaired. They want a technology which help them to recognize a traffic light. It's very difficult for them to estimate that when is signal stopped and when they have to cross the road. They cannot see the lights because they have extreme lights sensitivity problem. Some of them are color blind. They face irritation, pain, and discomfort [26].

Specify the Requirements

According to the extensive literature analysis, the most typical requirements are [27]:

2. Adequate knowledge about the surroundings,
3. Lightweight,
4. Low cost,
5. Safety,
6. Simple user interface,
7. Simple carrying technique
8. Visual suitability.

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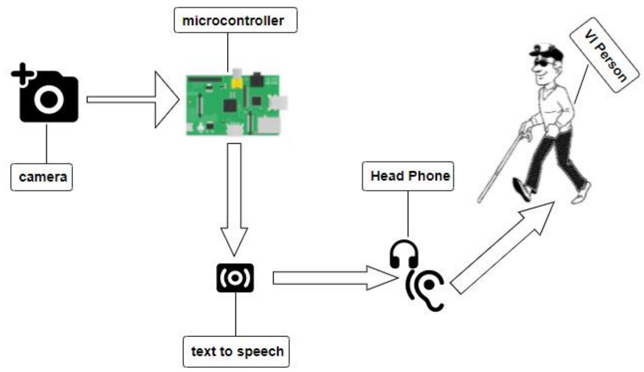

Figure 2: Conceptual design of proposed model (Talking-Cap).

Design Solution

After keeping in mind the above goals of VI people. I have made a conceptual Design of the proposed model shown in Figure 2. Which is equipped with a camera, microcontroller for image processing, text to speech smart device, and headphones. A camera has embedded on the top of the cap that will take an image of a traffic signal by pressing the button from VI person. The microcontroller will just scan the color in the captured image, identify the active/bright colour and then the smart device converts the processing mechanism from text to speech and give the output through non-visual way in earphone to VI person. For example, if the colour of light is red then it will send message that colour is red as shown in Figure 3. And user can hold a simple stick just for its stability and balance.

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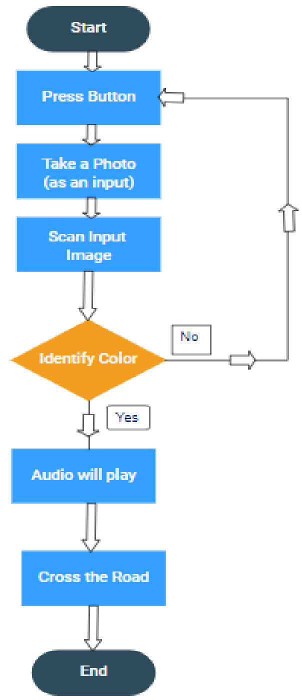

Figure 3: Flow chart of Talking-Cap

Prototype Development

In this paper, a prototype of cap is designed and named it "Talking cap" which is very unique it is based on the characteristics of the cap and it separates it from the existing solutions that are useful for visually impaired people. I have named it Talking Cap because it will give the message to the people through the voice which they can easily understand without any problem. In this prototype, I have made the conceptual design of the entire physical model. This prototype provides an attractive and user-friendly interface as shown in Figure 4. And also four eye tests are designed to evaluate the usability of the prototype as shown in Figure 5

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Figure 4: Main Screen

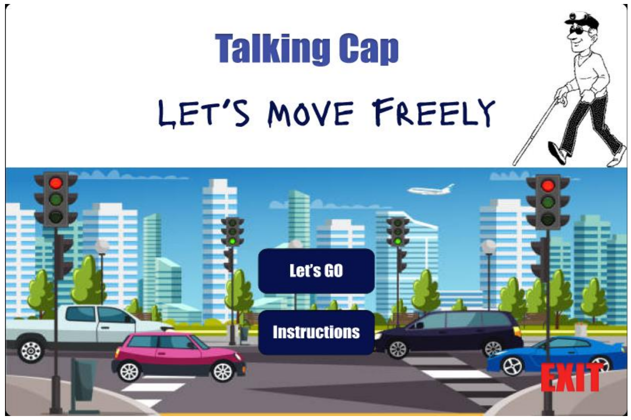
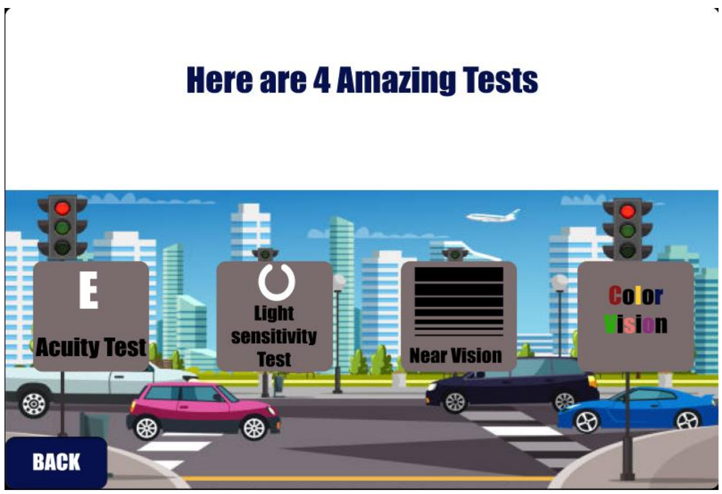


Figure 5: Tests Screen



Data Collection and Sampling

A simple group of users from the specified domain is required for a usability test. For this purpose, 96 school students were selected for the usability evaluation of the prototype. The students of The Knowledge School Okara (Al-Rehman Campus) are chosen as participants consisting of 48 girls and 48 boys who belong to different age groups. In Table 1, their detail is mentioned.

Table 1: Categorization of Participants on the Basis of Age Groups and Classes

No	No. of participants	Males	Females	Age group	Classes
1	32	16	16	5-8	Class 1 to Class 2
2	32	16	16	9-12	Class 3 to Class 6th
3	32	16	16	13-16	Class 7th to Class 10th

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The total no. of participants are 96 in each group containing 32 students which is further divided into 16 male and 16 female. The ages of participants are categorized as 5 to 8, 9 to 12, and 13 to 16. All of the attendees were given a briefing on their responsibilities during a little training session, which means what they have to perform.

Experimentation

In experimentation, students were categorized into three groups and created multiple tasks using four tests that were designed in the prototype. Each group was asked to perform three tasks and each task was timed differently and participants had to complete the task within a given time. Their details are given below [28].

Group-1

In group 1, three tasks were created, and asked the students to perform them. Task 1 is about to open the test 1, understand the direction of alphabet (E). The main purpose was to check the flow of start, back, and exit and the hesitancy of children was to be eliminated. This task was given 2 minutes to be completed. Task 2 is related to identifying the colors, before starting the acuity test three color cards as shown in Figure 6 are made in the prototype participants were asked to identify the color.

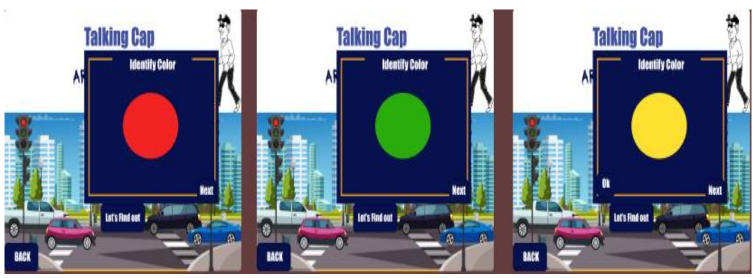

Figure 6: Color Cards to identify the colors

The purpose was to make it more interesting for children and more knowledgeable for children. Two minutes were allocated to complete this task. In task 3, a complete test 1 is performed by the group 1 participants. This task was allocated time 5 minutes. Because it had to be performed in two ways, in the first stage the participant had to close his left-eye to indicate the direction of the changing image. The goal was to evaluate how effectively the eye could see details and shapes of items from a certain distance. Figure 7 shows group-1 participants performing tasks.

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Figure 7: Group 1 participants performing tasks

Group-2

Figure 8 shows that group 2 participants performing tasks, three tasks were assigned to students. Task 1 is about to open the prototype, understand the instructions. The main purpose was to check the flow of start, back, and exit and to eliminate the hesitation of children. This task was given 3 minutes to be completed. In task 2, prototype participants were asked to identify the color as well as understand the rules for these colors and understand the directions of shapes. This part relates to traffic light colors and their purpose. The purpose was to make it more interesting for children and also enhance their knowledge. Five minutes were allocated to complete this task. This time was decided according to their age group.

Figure 8: Group 2 participants performing tasks

In task 3, participants were asked to perform a light sensitivity test. The goal was to evaluate how effectively the eye could see the shapes of items from a certain distance with a bright and dark colors. This task had to be performed in two ways, in the first stage the participant had to close his left eye to indicate the direction of the changing image and in the second stage, he/she had to do the same with his right eye closed. And participants were also asked to perform color vision (only 4 plates of the Ishihara test were asked to identify). The purpose was to check their congenital red-green color blindness. This task was allocated time10 minutes.

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Group-3

In this group, as shown in Figure 9 participants performed three tasks first was to explore different tabs. The purpose was to explore the interface, layout, and information put on the screens of the prototype. 10 minutes were given to perform this task. In task 2, participants were asked to perform a near vision task. In the near vision, a paragraph with different text sizes was given, and asked to read it. The text was started from bold and decreased to light text. 15 minutes were allocated for it. Task 3 is related to color vision, an Ishihara test was asked to perform. We have used 12 plates' Ishihara test. The goal was to evaluate how effectively the eye could read the detail of items from a certain distance and also differentiate colors. The purpose was to check their congenital red-green color blindness. This task was allocated 20 minutes time.

Figure 9: Group 3 participants performing tasks

Usability Evaluation

Usability is not a single-dimensional it's a combination of factors, according to ISO 9241-11 usability is evaluated with the three measurement factors which are clearly described below [29].

Effectiveness

The precision and completeness in which users attain their objectives. The completion rate can be used to determine effectiveness.

Calculated as:

$$\text{Effectiveness} = \text{total task completed} / \text{total task undertaken} * 100$$

Efficiency

Efficiency is evaluated in terms of time, the time a user takes to complete a task. it can be calculated as:

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$$Time\ based\ Efficiency = \frac{\sum_{j=1}^{R}\sum_{i=1}^{N}\frac{n_{ij}}{t_{ij}}}{N \times R}$$

Equation 1: Efficiency

Here,

R = No. of users

N = total No. of task

nij = user completed a task

tij = time by user j to complete a task i.

Satisfaction

After completing a task successfully, a questionnaire is given to the user for taking feedback on whether a task was easy or difficult. Typically a questionnaire consists of 5 questions. Mostly ASQ (after-scenario question) questionnaire is used. It contains 3 questions. Each question is ranked on seven point from strongly disagree (1) to strongly agree (7).

4. RESULTS AND DISCUSSION

In this section, the result of the effectiveness, efficiency, and user satisfaction of the prototype will be discussed. This section mainly focuses on the findings which are derived during experimentations. Moreover, this chapter is categorized into three main parts Effectiveness, Efficiency, and Satisfaction.

Effectiveness

Figure 10 shows the 94% effectiveness of both boys and girls for task 1. Whereas task 2 has 100% effectiveness for both boys and girls. It clearly shows that all the participants successfully performed task 2. Although, tasks 3 effectiveness is the same as the effectiveness of task 1 which is 94%.

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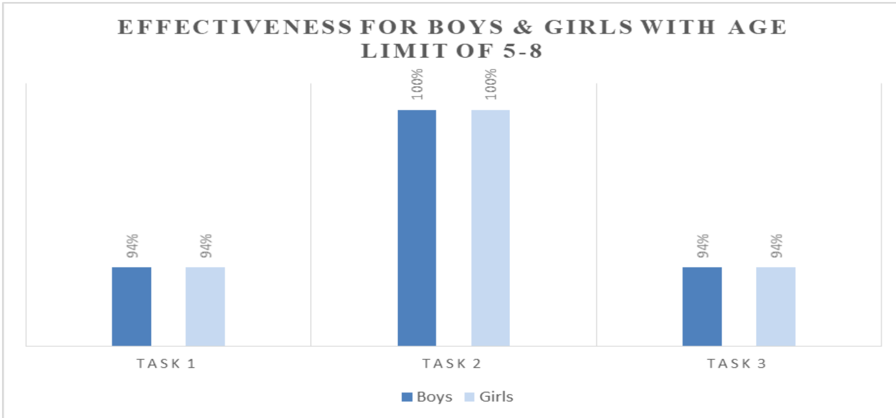

Figure 10: Effectiveness for Boys and Girls of Group 1

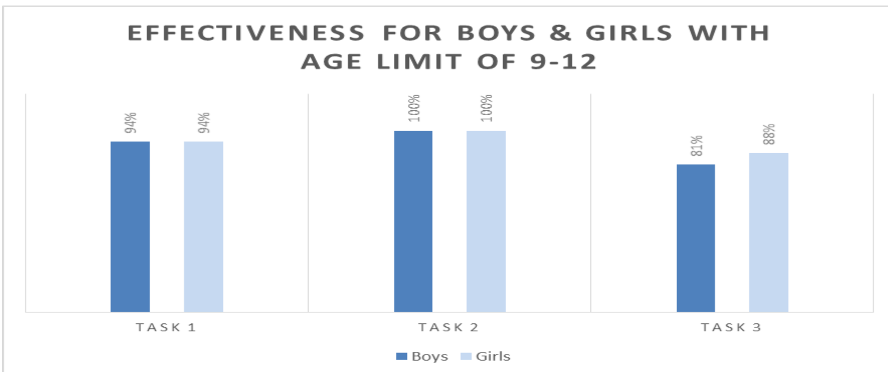

Figure 11: Effectiveness for Boys and Girls of Group 2

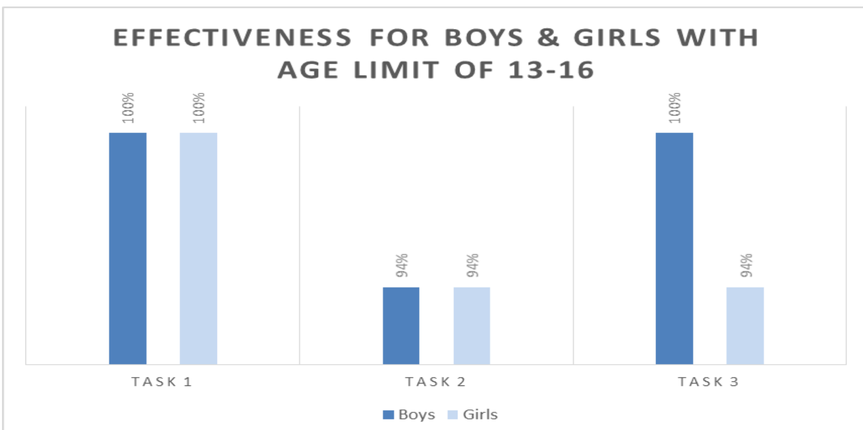

Figure 12: Effectiveness for Boys and Girls of Group 3

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Figure 11 shows the effectiveness of group 2 boys and girls in which task 1 have 94% effectiveness for both boys and girls. Whereas task 2 was performed successfully by all the participants it has 100% effectiveness for both boys and girls. Although, in task 3 effectiveness seems to vary as the effectiveness for boys is 81% while girls' effectiveness is higher than that of boys which is 88%. Figure 12 shows that task 1 was performed successfully by all the participants it has 100% effectiveness for both boys and girls. Task 2 illustrates 94% effectiveness for both boys and girls. In fact, in task 3 effectiveness seems to be different here, all boys performed task 3 successfully their effectiveness in task 3 is 100% however girls' effectiveness is 94%.

Efficiency

The following graphs show the group-wise efficiency which is calculated using the efficiency formula.

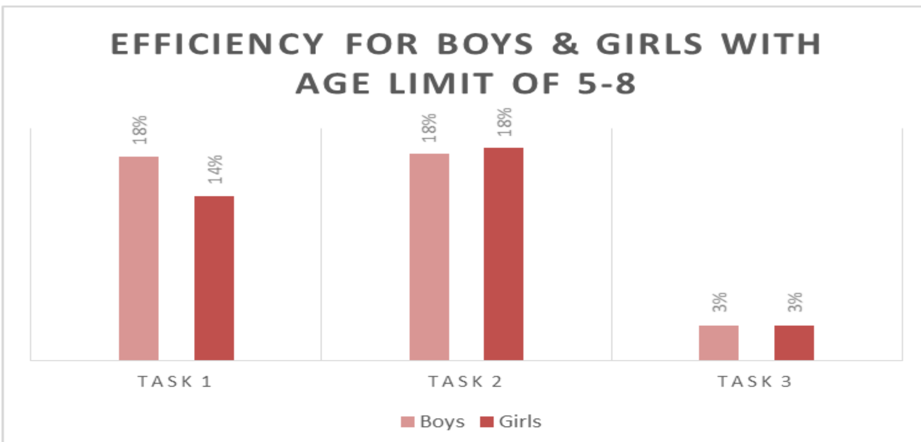

Figure 13: Efficiency for Boys and Girls of Group 1

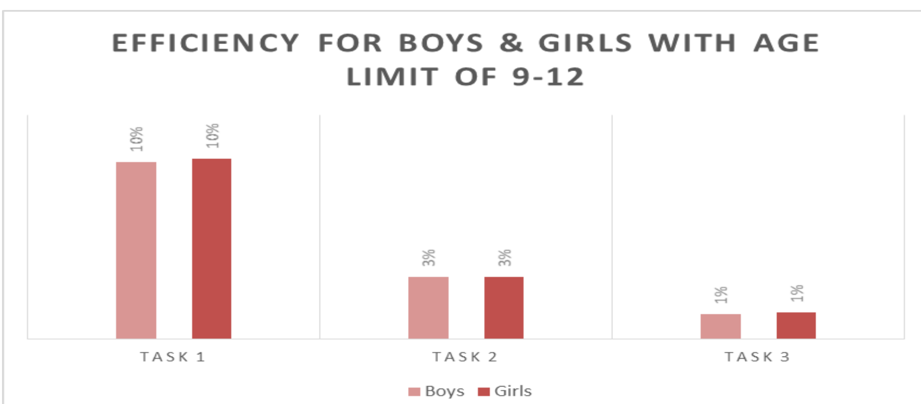

Figure 14: Efficiency for Boys and Girls of Group 2

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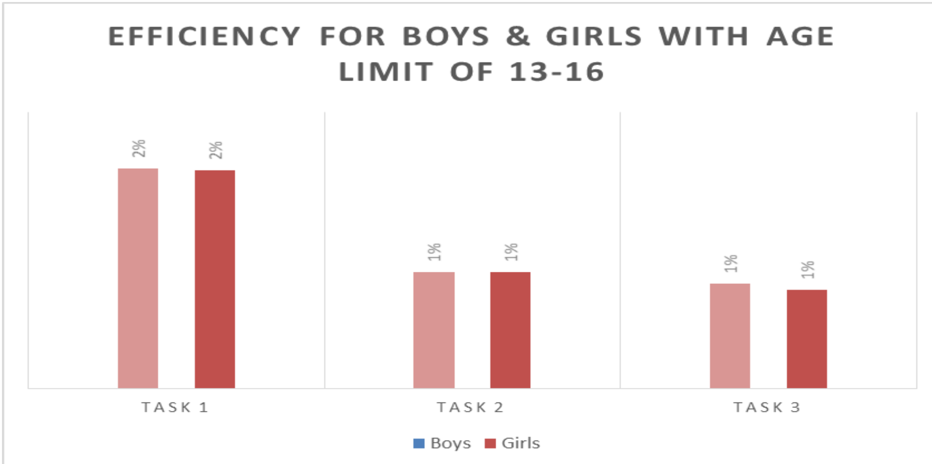

Figure 15: Efficiency for Boys and Girls of Group 3

Figure 13 shows that group 1 efficiency by tasks is as follows: 18% versus 14% for task 1, 18% for task 2, and however, in task 3, the efficiency rate is 3%. Similarly, Figure 14 shows the same efficiency for both boys and girls for task 1 is 10%, for task 2 is 3% and for task 3 is 1%. And so on for Group 3 Figure 15 shows the same efficiency for both boys and girls which is 2% for task 1, 1% for task 2, and 1% for task 3 as well.

Satisfaction

In this subsection after the scenario questionnaire (ASQ) was given to the participants to measure user satisfaction. It contains 3 questions. Each question was ranked on seven-point from strongly disagree (1) to strongly agree (7). In this questionnaire about the ease of the task, enough amount of time was given and about the guidance questions were asked.

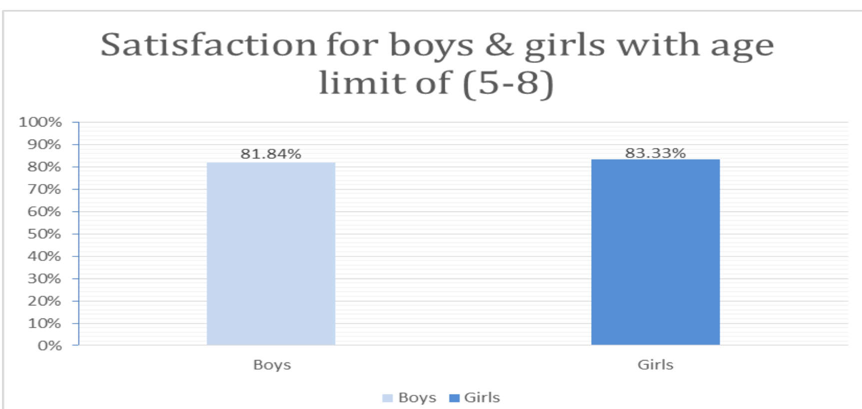

Figure 16: Satisfaction for boys and girls with age limit 5 to 8

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DOI 10.17605/OSF.IO/JSUYB

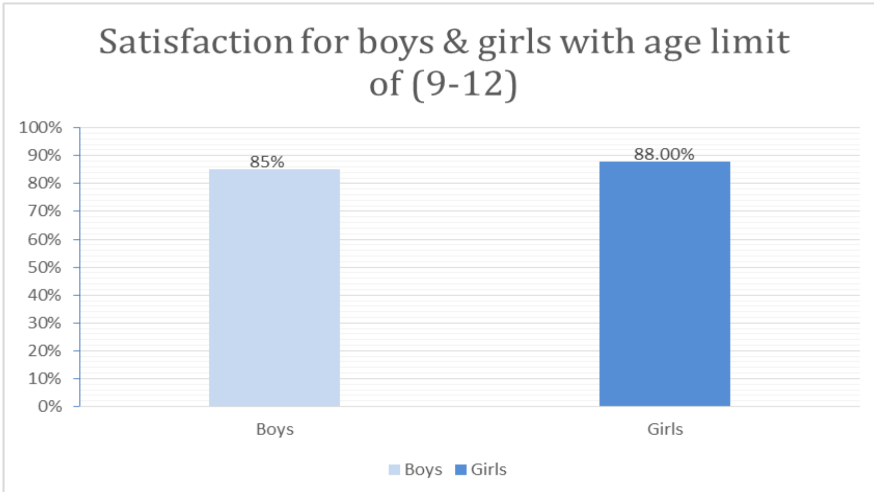

Figure 17: Satisfaction for boys and girls with age limit 9 to 12

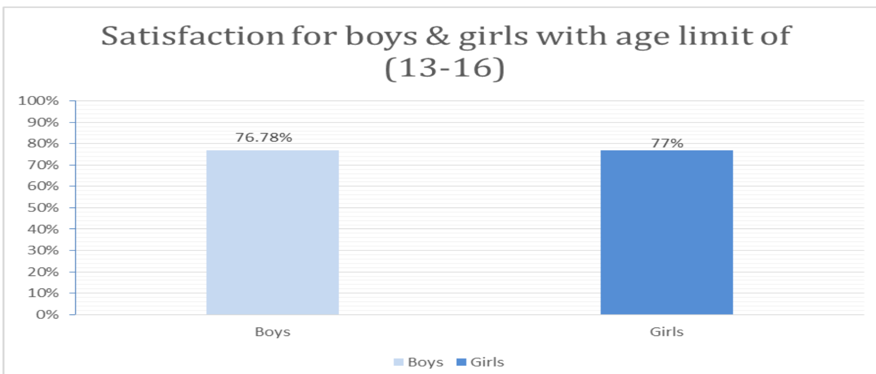

Figure 18: Satisfaction for boys and girls with age limit 13 to 16

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 41 Issue: 12-2022
DOI 10.17605/OSF.IO/JSUYB

The above results show that in group 1 as shown in Figure 16 and group 2 as shown in Figure 17 girls had a higher level of satisfaction than boys. In group 1, girls have 83.33% and boys have 81.84%. And In group 2 girls have 88% and boys have 85% satisfaction. Whereas in group 3 as shown in Figure 18, satisfaction scores are below from the first two groups, and but also girls had higher satisfaction than boys which is 77%. However, boys scored 76.78%.

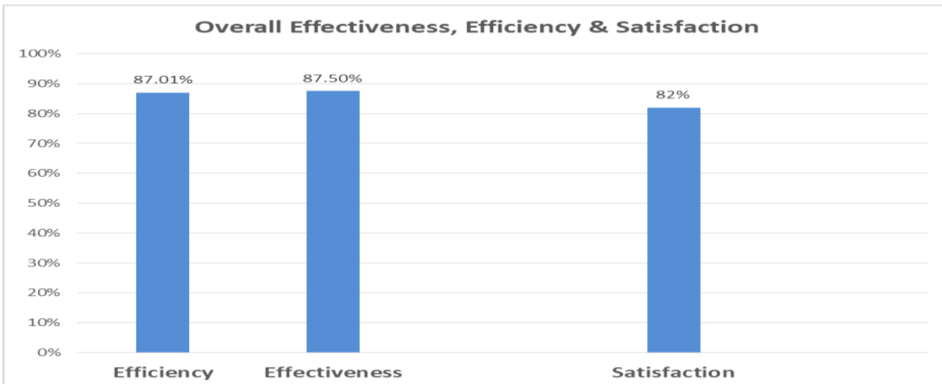

Figure 19: Overall Effectiveness, Efficiency, and Satisfaction

5. CONCLUSION

This project has chosen to address a problem that affects the visually impaired. Crossing a road; or, to be more precise: Recognition of Pedestrian Traffic Lights. First, I tried to uncover the challenges and needs that visually impaired people face when crossing a signalized intersection in order to explain the supporting system for them to cross safely at a signalized intersection. A literature review was conducted, and the existing techniques provided were reviewed. Well, we have suggested a lightweight talking cap as a solution for the visually impaired to understand the traffic lights. The proposed model is based on the UCD process model in which firstly, we identified the problems, defined the users' context, and specified the user requirements, the prototype had developed as a proposed solution in which the conceptual functionality of the cap is defined and we named it the talking cap because of its functionality. And second last step was experimentation for that we visited a school and then students were asked to perform some tasks. These tasks were categorized on the basis of age group. And lastly, for analyzing the performance of the prototype usability techniques were used as shown in Figure 19, the overall effectiveness of the prototype was 87.50%. While its efficiency is 87.01% and after performing each task, a questionnaire was given to each student to determine user satisfaction, which resulted in 82%. We have achieved a very good user experience of effectiveness, efficiency, and satisfaction.

FUTURE WORK

The fact that this research offers recommendations and tactics for creating a user-friendly, user-interactive design opens up new opportunities for the researcher to create something original that can satisfy the genuine needs of a user, which might have a significant impact on fixing VIs concerns. So, in the future, we will try to make it finest, and more attractive as per users' demands.

Authors Contribution: All authors have equal contribution.

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ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 41 Issue: 12-2022
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