Ocufy: A Mobile Eye-Testing Interface

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Abstract — Eye-testing is one of the most important health check-up required by all individuals. However, it turns out that it is also one of the most neglected check-ups of all time. Most people do not anticipate the need for checking their eyes until their vision is affected. Due to these reasons, we created Ocufy - a mobile eye testing interface with which any user can check their eye acuity in just under five minutes. Not only is it free to use for everyone, but it also provides one of the most accurate results of a mobile eye test. This accuracy is achieved with the help of an algorithm which finds the user's screen-to-face distance and starts the test only after a minimum threshold is achieved thus providing the most authentic results. We performed the evaluation with 10 people and found out that the application provided accurate results 85% of the time. Moreover, the application received an average rating of 4.5/5 with over 80% respondents recommending it to use it next time to check their eyes.

Keywords - eye test; natural human interaction; diagnosis; mobile devices; facial detection

Concepts - human-centered computing; HCI design and evaluation methods

I. INTRODUCTION

Today, with advances in technology, the human eye is getting more and more hitched to the digital screen making it prone to blurred vision. A study published in the journal Ophthalmology found that on current trends, 50 percent of people on the planet would need glasses or contact lenses with 10 percent suffering from severe myopia [1]. Our application relieves the pain of the user who has no access to an eye clinic. Also, it is for the user who does not anticipate the need for checking their eye until their vision is affected.

A. Motivation

With each author diagnosed with myopia, one of the major motivation for this research project was to make people realize the importance of an eye test before there is a need for it. It is recommended for each person to get an eye test at least every two years. In one of the research study conducted, 80% of respondents believed that sight is the most important sense, however, a third hadn't gotten an eye test in four years or more, with a worrying 6% have never had an eye exam [2].

According to WHO, an estimated 253 million people live with vision impairment where 36 million are blind and 217 million have moderate to severe vision impairment. 81% of people who are blind or have moderate or severe vision impairment are aged 50 years and above [3]. The other affected people are especially children and people from low and middle-income countries. Lastly, women are most affected by this as at least 2/3rd of blind people are women [4]. But the most important factor for motivation was that 80 percent of all vision impairment can be prevented or cured.

The rest of the paper is organized as follows. Section II covers the literature review, which throws light on the work done in the area of finding eye acuity by the user in the mobile eye vision sector. Section III presents the proposed approach to implement the intended solution. Section IV describes the proposed approach of making the application mobile. Section V thus describes the research into understanding the traditional eye testing methods and further finding the possibility of making the test mobile. Section V and VI provide the actual system architecture and the implementation of each of the modules. Finally, Section VII most importantly provides results of the user evaluation study conducted to verify the claims of the accuracy of the application. The paper ends with conclusion and direction for future work.

II. LITERATURE SURVEY

Different researchers and applications have presented different approaches that help the user to conduct an eye test. Both professional and personal systems are available with the help of which a user can test his/her eye acuity. However, there are multiple flaws in these systems which we will cover in the next section. In this section, the related work on eye acuity test has been explored. Let us now see some of the prominent eye acuity testing systems currently available in the market [5].

A. Professional Existing Systems

There are a few state-of-the-art professional solutions that can be adopted by ophthalmologists as listed below:

1) 20/20 Vision (Canela Software) [6]: This software is a desktop applications for professional use. With tests ranging from customizable, randomized acuity charts to complex visual diagnostic tests, 20/20 Vision is suitable for optometry, ophthalmology, and clinical research alike.

2) PVVAT™ (Precision Vision) [7] : This application shows the tools used by oculists (eye charts, Snellen tables, etc.) on the desired screen to test patients. The screen can be either a computer monitor or an external display.

B. Personal Use Existing Systems

The proliferation of mobile phones has given rise to another set of interesting software solutions that allow users to self-test their visual acuity with a cell phone or a portable device. The relevant applications are:

1) Eye Test (Healthcare4mobile) [8]: This is a free mobile application available on the Google play store. It has various eye tests to perform an eye exam for complete vision screening and detection of possible eye problems.

2) Eye Chart HD (Dok LLC) [9]: This application is a pocket vision screener with randomized Snellen, Sloan, Tumbling E, and Landolt C charts to offer a rough but useful screen of visual acuity.

C. Problems in Existing Systems

The systems discussed in the previous section has various limitations that make the vision testing and screening extremely difficult for the user. The reasons are:

1. Too Expensive for the average user

Most of the professional and accurate eye testing solutions are developed for oculists who can afford to buy these expensive software for their clinics. The average user cannot purchase these software as they are too expensive and are complicated to set up initially without the help of an expert user. For instance, the Canela 20/20 Vision offers their software for $49 or $69 monthly pricing plans while the Precision vision software is priced as high as $1125.

2. Incorrect Results provided by most solutions:

To overcome the issue of expensive software and due to the increased availability of smartphones, many software developers hopped on the idea of making an eye testing application for smartphones. While this is a novel idea with which user can easily check their eye vision instantly, it seldom provides any accurate results. The main reason being that the same test is provided for every screen size and every person irrespective of the distance at which they are holding their phones.

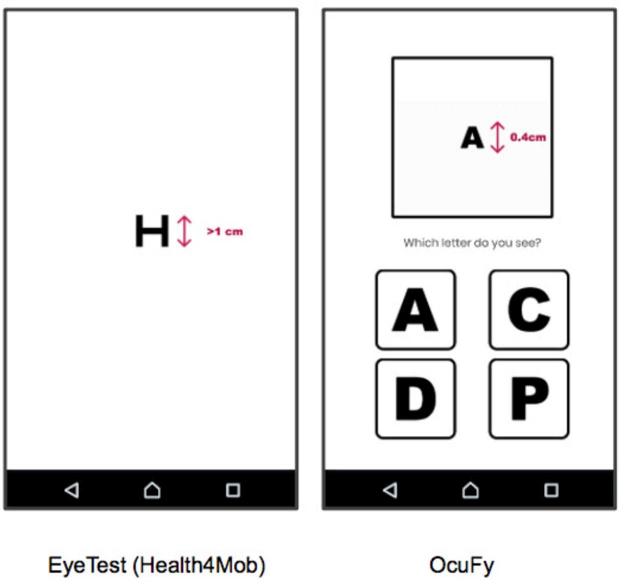

Figure 1 Comparison of both applications where the first Optotype is shown where Ocufy shows the test based on the face-to-screen distance of the user.

Considering the various issues mentioned in the existing systems and their importance in measuring eye acuity on a smartphone, it was decided to address these issues in the proposed system. The system must be able to provide the most accurate results. It should be able to give a correct test irrespective of the screen size. Also, the test must be unique for a user on the basis of the phone-to-screen distance. Only then can the system can be fit to be used and trusted by the users for checking their eyes. Details of the proposed approach are given in the next section.

III. PROPOSED APPROACH

It is really important to provide correct results in a diagnosis. Only if the results are accurate will the user trust an application. We intend to provide the most accurate results of a mobile eye testing interface. This requires extensive research by understanding how eye testing works in the first place. In our proposed approach, we intend to create a system which first identifies the phone-to-face distance of the user. Then this distance is used to find whether a unique test for an individual can be provided. If the distance is too small, the test cannot be conducted properly. Hence, a minimum threshold would be set for the user to be able to begin the test.

Once the distance metric has been taken care of, the user is exposed to a quiz-like test where different characters (optotypes) of varying sizes to are presented. The user has to close each eye sequentially to get an eye score for each of the eyes. This score is calculated on the basis of the number of characters the user is able to correctly identify. This test is based on the Snellen Chart which is the de facto standard for measuring eye acuity. It is also one of the most commonly used eye chart. We will discuss about this chart and the ways in which it can be made mobile in the next section.

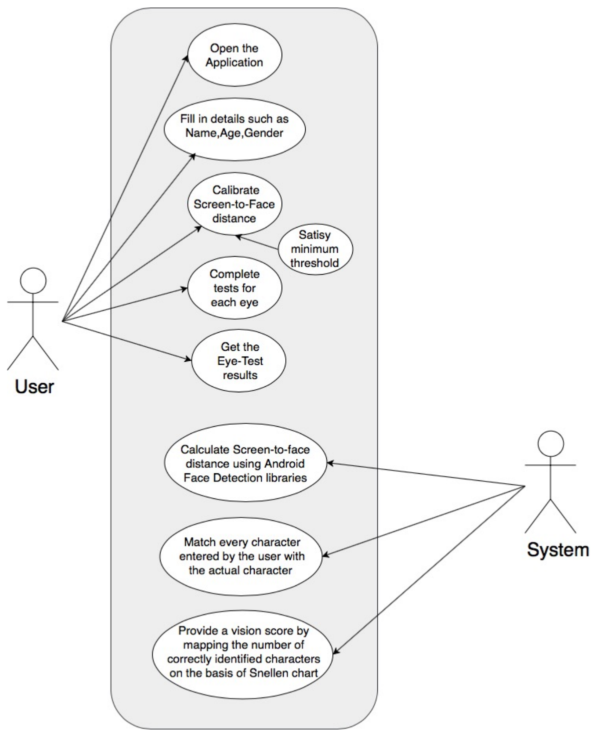

Figure 2 Proposed System Flow

IV. METHOD

To make the eye test mobile, we first need to understand how the traditional eye testing system works. We also need to understand how the results are evaluated for this test. Moreover, it has to be learned how can this method be converted so as to be viable to implement in a small phone screen.

A. Understanding the Snellen Chart

A Snellen chart is an eye chart that can be used to measure visual acuity. Snellen charts are named after the Dutch ophthalmologist Herman Snellen, who developed the chart in 1862. The normal Snellen chart is printed with eleven lines of block letters. The first line consists of one very large letter, which may be one of several letters, for example, E, H, or N. Subsequent rows have increasing numbers of letters that decrease in size. A person taking the test covers one eye from 6 meters or 20 feet away, and reads aloud the letters of each row, beginning at the top. The smallest row that can be read accurately indicates the visual acuity in that specific eye. The symbols on an acuity chart are formally known as "optotypes"[10]

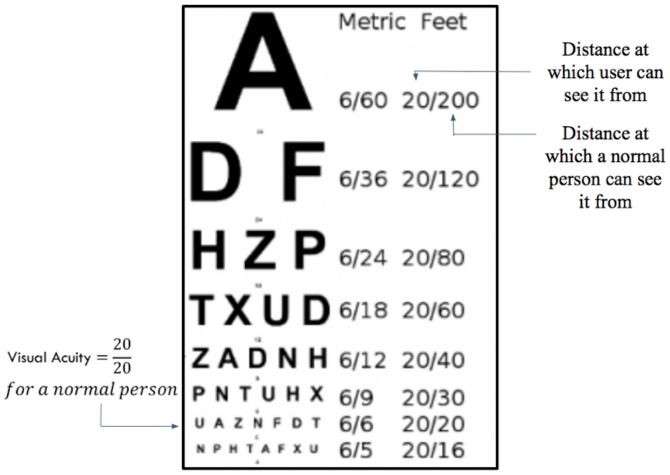

Figure 3 A Snellen Chart with both metrics

B. Optotypes and their Characteristics

In the case of the traditional Snellen chart, the optotypes have the appearance of block letters and are intended to be seen and read as letters. They are not, however, letters from any ordinary typographer's font. They have a particular, simple geometry with some unique characteristics. The following are the features of the optotypes:

- Snellen developed optotypes using symbols based in a 5×5-unit grid so that the size of the critical detail (each gap width) subtends 1/5th of the overall height
- The thickness of the lines equals the thickness of the white spaces between line
- The height and width of the optotype (letter) is five times the thickness of the line.

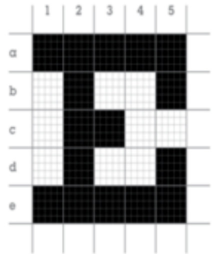

Figure 4 Optotype is a symbol based in 5*5 unit grid

C. Constructing Visual Acuity Chart

Before constructing a Visual Acuity Chart, one needs to know and decide what kind of chart one wants to construct. There are actually different kinds of charts for visual acuity measurement with Snellen chart being the most common. Based on construction they generally fall into two categories, Snellen and logMAR [11]. Visual Acuity Chart can be constructed based on 2 criteria:

1. Measurement of minimum separable acuity
2. Measurement of minimum recognizable acuity

Two distinct points can only be recognized as separate when they subtend an angle of one minute arc at nodal point of eye.

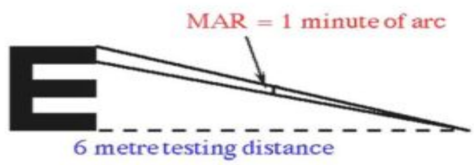

Figure 5 For a visual acuity of 20/20, one of the strokes of letter should subtend one minute of the arc at the eye. Therefore, the minimum angle of resolution(MAR) is one minute of arc

D. Defining Standard Vision

Snellen defined "standard vision" as the ability to recognize one of the optotypes when it subtends an angle of 5 minutes of arc. It is a representation of visual acuity in the form of a fraction (e.g. 6/6, 20/20) in which the numerator is the testing distance, and the denominator is the distance at which smallest Snellen letter read by the eye has an angular size of 5 minutes [12].

$$\text{Snellen's fraction} = \frac{\text{Distance at which test is done}}{\text{Distance at which the smallest optotypes subtends an angle of } 5' \text{ arc}}$$

For example, 6/60 means the ability to see an object only at 6 meters which should be normally seen at 60 meters. At 6-meter (20 ft.), the letters on the 6/60 (or 20/20) line should subtend 5 minutes of arc (each limb of the letters subtend 1 minute of arc)

E. *Finding the Height and Width of Optotypes for Mobiles*

Finally, the knowledge of all this information can be used to find the dimensions of the optotypes for conducting an eye test in mobile. Only if we strictly follow these dimensions, can we get an accurate eye result. We know that at exactly 6 meters distance from the patient, the letters on the 6/6 line shall subtend 5 minutes of arc (such that the individual limbs of the letters subtend 1 minute of arc), which means that the chart should be sized such that these letters are 8.73 mm tall and the topmost (6/60) "E" should be 87.3 mm tall. We get the formula

$$w = 2d\, tan\frac{\theta}{2}$$

where w is the optotype height or width (which are the same due to the optotype being on a square grid), d is the distance from eye to chart, and θ is the angle subtended by the optotype (which is 5 arcminutes as specified by Snellen).

These calculations result into finding a scaling factor by which we can decide the size of the topmost optotype for a mobile eye test. It is found that the eye should be at a distance **68.76 times** the height of the top (6/60) letter. This is how human computer interaction methodologies and its understanding can be used to make these optotypes suitable for the phone's screen.

V. SYSTEM ARCHITECTURE

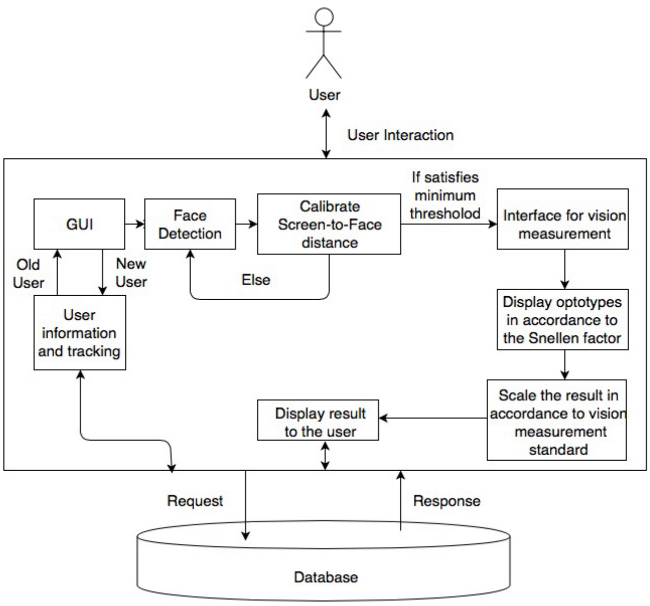

Figure 6 System Architecture

The first phase of designing the system is to select an architecture. Fig. 6 shows the architecture of the proposed system, where a 2-tier client-server architecture is selected. The main reason for selecting the said framework is that we can store the information of the user who wants to test their eyes. This will help us keep a record of the users while also being able to track users history of eye check-ups. Lastly, by getting the users information, we can create a unique test based on the user's age, gender, location etc. Hence a database is used to store the information of the user's details and his/her eye test results. The architecture of the system is thus divided into two layers, namely, the client side layer and the server side layer. At the client side, the user interacts with the system using the Graphical User Interface (GUI) where the user first has to enter his/her information i.e. the name, age, and gender. Then, the face detection module starts where the user has to calibrate and find the distance between the face and the screen. Once this distance is found and the minimum distance threshold is maintained, the user can proceed to give the test. This test involves the user to close one eye and answer all the questions. This same is repeated for the other eye.

VI. IMPLEMENTATION

Looking at the role played by each component of the system, let us see the implementation of each of the module of the system with respect to the proposed approach. In order to implement this system, various tools and technologies are required. Android Studio/Eclipse can be used to make the android application. Each of the modules and their working has been described below:

1) *GUI Module:* This module is the interface with which the user can interact with the application. On starting the app, the user is asked a few questions such as his/her name, age, and gender. This information is stored in the database for a new user. On the other hand, if the user is an old user, this step can be skipped. At the end of the test, the results of the user's eye test are stored so as to keep a record of the same.

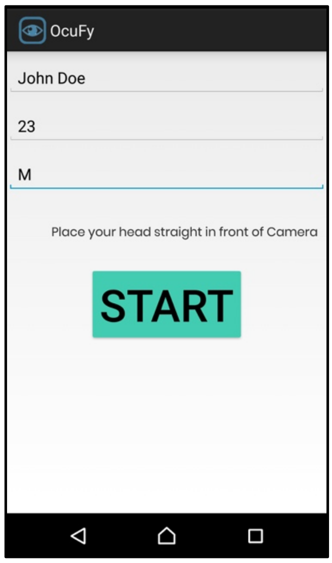

Figure 7 Application GUI on starting

2) *Face detecion Module:* This module is one of the most important part of the application. This helps in finding the distance between the phone and the screen of the user. The face detection can be done with the help of pre-built Android Face Detection libraries. In turn, this distance parameter helps to build the most accurate eye testing application. The detected face can provide us the results of the distance between the eyes. The algorithm for finding the distance of phone-to-face is based

on this value of the distance between the eyes. An object or a "distance" will seem smaller once its further away from the camera than when it's closer to it. So one should be able to calculate the distance between camera and face while using the eye distance at a reference length, in our case 29.7cm (the length of an A4 paper), and multiplying the reference length with the change of eye distance[13].

Figure 8 Using Eye Distance to find the corresponding face-to-screen distance of the user [Image Credits: Sims Wiki]

3) *Calibration Module*: Whenever the user face detection has been initiated, this detection must be able to find the distance between the eyes. Hence a calibration is required in which the user's eyes are identified. A green dot is shown on the eyes of the user so that the user can be sure that the face detection is properly calibrated. Thus, the corresponding distance is calculated between the phone and the face.

Figure 9 User Calibrating the face detection module to find the eye points and thus the distance between the face and eyes [Image Credits: Sims Wiki]

4) *Vision Measurement Interface:* After the distance between the phone-to-face is calculated, it is checked whether that distance is above the minimum threshold. The minimum threshold is set in such a way that the smallest optotype to be shown in the test must be visible to the naked eye. This is the special condition because the phone screens are too small for the eye test to be conducted if the minimum threshold value is not satisfied. After the verification, the user can now start the test in which the eye acuity is measured. The test has to be repeated two times for each eye individually. This makes sure that we get the eye test result correct for each of the eyes.

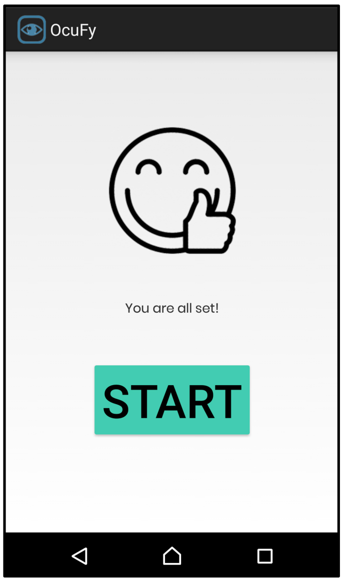

Figure 10 The start screen before the beginning of the test

5) *Displaying Optotypes:* The test is conducted in the manner that the optotypes on basis of a Snellen factor are shown to the user. These optotypes keep decreasing in size. This decrease in size is also kept uniform to get the most accurate result. After looking at the optotype, the user has an option to select which symbol he/she just saw on the screen. The user can select from one of the four options provided. The options are also given in such a way that the user cannot simply guess on the basis of the shape of the optotype shown. For example, when the optotype "C" is shown, the options are kept in a way that user cannot guess the answer on the basis of the shape of C. So the options are shown along with "C" are generally "G", "O", "D" etc.

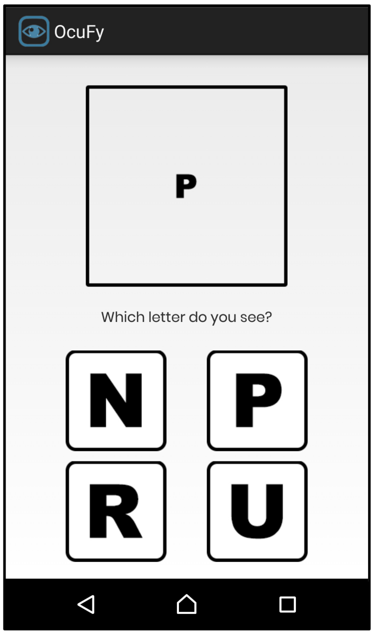

Figure 11 The test showing optotypes in order to determine the eye acuity

6) *Scaling the Result to Vision Measurement Standard:* The score of tests is simply the number of answers correctly identified by the user. However, this score has to be converted to a vision score on the basis of the Snellen chart results. For example, if the user is able to correctly identify till 5^{th} line but is not able to answer correctly then onwards, he/she has a vision score of "20/40" w.r.t. the Snellen chart. Hence, the Vision Score for each of the eyes has to be computed on the basis of the results of the eye tests. The pseudo code for our algorithm is given as follows:

```
Pseudo Code:

Estimate_scree_to_face_distance():
        (reference_eye_dist,scree_to_face_dist) =
        set_reference_parameters();
        val = get_change_in_eye_dist();
        return val*reference_eye_dist;

compute_scree_to_face_distance():
        face_detection();
        detecting_distance_between_eyes();
        result = estimate_scree_to_face_distance();
        return result;

display_result(left_vision,right_vision):
        (left_result,right_result) =
        scalevision(left_vision,right_vision,snellen
        _parameters);
        return (left_result,right_result);

L1 : eye_test():
        get_user_details(name,age,sex);
        dist = compute_scree_to_face_distance();
        while(dist < min_threshold)
                dist = compute_scree_to_face_dist();
        begin_eye_test();
        left = calculate_vision_for_left_eye();
        right = calculate_vision_for_right_eye();
        display_result();
        repeat = repeat_test();
        if(repeat)
                goto L1;
        else
                end;
```

7) *Displaying the Result:* After the scaled vision score is computed by the system on the basis of the user's answers, this vision score is displayed to the user. This result can be considered as an eye report card by the users. If the vision is found to be improper, the user is immediately recommended to visit a nearby doctor to confirm the finding.

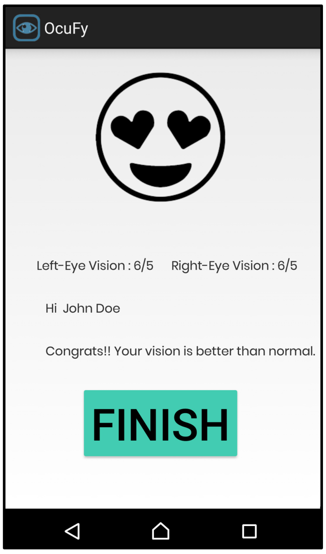

Figure 12 Test results are provided as eye report card with recommendations

VII. EVALUATION

In order to find the accuracy of the developed system, we conducted a user study where each user was given our system and another android application "EyeTest" available in the play store. The results of both these tests were recorded and also the original eye score of the user was recorded if the user had already conducted an eye test with a doctor before. The goal of the user study was to find out if the results provided by the application is accurate to the actual vision of the respondent.

Participants

10 respondents of the age group 20-35 participated in the study. There were total 8 boys and 2 girls in the survey. Also, a total of 3 people already had spectacles while one of the respondent had performed a LASIK surgery to remove the spectacles.

Apparatus

The study was conducted using our mobile (Sony Xperia XZ phone with screen size of 5.2 inch across, Full HD resolution with an IPS LCD Screen). The respondents were required to hold the phone at almost arm's length. This was managed with the implemented distance tracking technology. The respondents were required to answer the test questions on the phone itself

Study Design

The study was conducted on two applications. One being Ocufy while the other being "EyeTest" which is available on the Google PlayStore. The respondents were asked whether they have spectacles or not and their original vision score. There were 4 variables on which the tests were judged mainly
1) Normal Ocufy test (Left and Right eye)
2)Normal EyeTest test (Left and Right eye)
3) Ocufy (Both eyes)
4) EyeTest (Both Eyes).
This accounted for a total of 10 participants × (2 Tests × 2 Eyes) × 2 Tests = 80 Tests. Additionally, for the people with spectacles (3 people), there were another set of same tests with spectacles kept on. This accounted for another 3 participants × (2 Tests × 2 Eyes) × 2 Tests = 24 tests. Hence a total of 80 + 24 = 124 tests was conducted.

Tasks and Procedure

Prior to the test, the application was kept open for the respondents so that they can directly enter their information. After entering their information, they were required to calibrate the face detection module in which their eyes were identified and the distance between their eyes and phone was calculated. Once the distance was above the minimum threshold, the test would automatically begin. Then as described in the application, the respondent was required to cover one eye with one hand and hold the phone with the other hand at arm's length. The respondent was required to answer all the test questions shown after the optotype were shown in decreasing order. The same had to be repeated for the other eye. This concluded one test. The same would be performed on another application. It was made sure that the order of applications was randomized. After individual eye tests, the respondents were required to give the same two application tests with both eyes open so as to see the accuracy. After these 4 tests, the respondents with spectacles were required to give these same 4 tests again with their spectacles on. This was an additional measure to make sure that they are wearing the correct power of lens required.

Results

A lot of interesting findings were found in this user study. Five respondents were able to check their eyes and confirm that their vision is normal as described by the other application as well. Also, three of the respondents who had spectacles were able to find an almost accurate representation of their vision score proving that the results were genuine. To validate this claim, their spectacle tests also claimed proper vision score. There were 2 very interesting findings. First, a respondent who had conducted LASIK surgery (to remove lens) [14] found to have a 0.5 power score in one of the eyes. The same was found in both the applications along with the confirmation of low vision score in Both Eyes test (6/9, 50%). Hence, the respondent was advised to visit a doctor immediately. In another finding, one user who did not have spectacles initially was found to have a vision score of (6/9, 69%) in all the tests performed in both the applications. This was conclusive evidence that the respondent immediately required a doctor's visit.

Final Feedback

The application got an average rating of 4.5/5 from all the users with over 80% respondents claiming that they will recommend using it again for testing their eyes.

VIII. CONCLUSION

In this paper, we proposed, designed and implanted a mobile eye-testing interface called Ocufy which would let the users check their eye vision with a mobile phone application. We designed the algorithm for finding accurate eye vision results by first researching the basics of finding eye vision score and about the Snellen chart and its optotypes. HCI methodologies helped us understand the importance of correct and accurate representation of optotypes for genuine eye test result where a scaling factor was devised for showing eye tests on mobile phones. It was found that the phone-to-face distance must be 68.76 times the topmost optotype. This distance factor was calculated and implemented by facial and eye tracking of the user. Finally, a test was shown to the user if the user was a certain minimum threshold distance away from the phone. The answers to these tests were then scaled back to the original Snellen chart results which stand as a standard form of eye vision calculations. The application provided an 85% Accuracy of correct result prediction (Ocufy Individual Eye Test w.r.t. the Original Eye Vision) with an over 80% applicants recommending it using again to get an initial screening of their vision.

IX. FUTURE SCOPE

It is rightly said that 'What do you do after you achieve one goal? You look for another one'. During the implementation of this system, it is found that there are instances and scopes where the system could be improved. Following was the observations:

1) The face-to-phone distance measurement module can be kept completely running throughout the test which can pause the test if the user brings the phone nearby.
2) The face detection module can be further calibrated to monitor the inclination angle of the phone. This can make sure that the user is holding the phone at a correct angle to provide much more accurate results.
3) Provide relevant doctor suggestions in the nearby locality (using maps API) if the user requires to immediately check up with an ophthalmologist.
4) Increase the functionality of the application by providing tests to check color blindness, astigmatism, contrast/sensitivity, cataract detection, duo-chrome acuity etc.

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