iGlass: Mobile Application for Self-Eye Assessments

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***Abstract*—Adopting technology in decision-making has been a medical practice for many years now, using e-Health, M-health, and even telemedicine systems. Smartphones' availability and features have made health management possible anytime and anywhere. The eyes are more than a window to our soul; it is vital to our sight and vision. Eyesight is one of the human senses to give more attention through regular eye examinations. Believing that a corrected vision improves the quality of life led to developing a mobile application for visual acuity tests and color vision tests called "iGlass." The acuity test measures individuals' reading capacity, and the color vision test, also known as the Ishihara test, is for color blindness testing. The result of functionality testing for the visual acuity shows that the developed mobile application, using the LogMAR chart, effectively measured the patients' visual acuity with 90% accuracy. While the functionality testing result for the color blindness shows that the application using the Ishihara plate effectively measured if the user is colorblind or not with a 100% accuracy rate. The mobile application assessment was made by a licensed optometrist and compared with traditional methods. Based on the compatibility test result, which uses Firebase Test lab, a cloud-based platform that Google developed, and manual testing for the compatibility test to verify the results given by the Firebase. It shows that the iGlass application is said to be compatible and can run smoothly with an Android operating system Lollipop and above. Users were satisfied with the user interface and the ease of access of the application, with an average mean of 4.6666.**

***Index Terms*—mobile application, eye self-assessment, visual acuity, color blindness, LogMAR chart, Ishihara test**

I. Introduction

The medical sector has also adapted technology through different platforms like e-Health, m-Health, and telemedicine [1]. M-health or mobile health is defined as mobile phone use to support health objectives [2]. Mobile application is a rapidly growing sector consisting of programs or codes that run on a smartphone or tablet that performs a task that the user asks [3]. Visual Acuity Test is an eye exam that determines how well the user sees a symbol or a letter from a specific distance [4]. Study shows that the average screen time per day would be one (1) hour for children ages two (2) to twelve (12) years old and two (2) hours for teens and adults [5]. Screen time includes television, computer, mobile phones, and gaming devices. However, many of us are now working or studying at home, which results in us staring at our computer screen more often. However, many experts warn us of the adverse effects of staring at our computer screens for some time [6]. As of 2019, the world health organization reported 2.2 billion people who have vision impairment. One (1) billion of those could have been prevented from vision impairment if detected early; that is why it is essential to have a regular eye check-up to ensure people's eye health [7]. This paper developed an application that addresses the visual acuity and color blindness of users who need an eye assessment using smartphones.

A. Full-Sized Camera-Ready (CR) Copy

The main objective of this study is to develop the iGlass mobile application for eye assessment to help the user check their eye condition. Specifically, this research aims (1) to provide virtual eye assessment; (2) to implement an eye assessment feature that allows evaluating a patient's health condition relative to color blindness and visual acuity; (3) to provide a history log feature to help the user monitor the previous result of the condition of their eyes.

B. Scope and Delimitation

For the visual acuity test, the application shall use the Logarithm of the Minimum Angle of Resolution (LogMAR) chart as the instrument to measure visual acuity [8]. Specifically, this study shall use the Early Treatment Diabetic Retinopathy Study (ETDRS) design of the chart, which uses Sloan letters (C, D, H, K, N, O, R, S, V, and Z) [9].

The Ishihara test [10] assesses whether the user is colorblind and falls under the different types of colorblindness. This study uses 25 plates from the Ishihara test, and the user must read the number in the plate to proceed to the next plate. For the scoring method of the Ishihara test, the first plate will be shown only for the patient's readiness to take the assessment.

II. Related Studies

A published study for a mobile visual acuity assessment application developed by Akbulut *et al.* is called AcuMob [11]. This study used the Xamarin framework in developing the application and voice

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commands for the client to interact with the app. Its primary aim was to give users an estimation of their vision condition, as they would be able to tell whether they have visual problems or not without having to visit the ophthalmologist or optometrist. The result of this study has good remarks based on the experiment conducted user acceptance testing.

The study of Silverstein *et al.* developed a system related to visual acuity amid the coronavirus disease-2019 (COVID-19). As the world began to rely more on telemedicine to conduct consultations, they researched phone-based visual acuity tests in a pediatric setting. Their respondents were children to teens aged 3-18 years old who were all patients of one pediatric ophthalmologist. This study evaluated the mobile application GoCheck Kids, a visual acuity test application, compared to the face-to-face protocol of the eye doctor [12].

There have been implementations of building data warehouses using electronic health records of patients in ophthalmological centers. These studies benefit patients and doctors alike in that both can visualize the data of patients. This study by Kortüm *et al.* was a success, providing improvements in data classification [13].

The application based on speech recognition developed by Shameem *et al.*, with a predetermined eye-to-device distance, developed an eye vision tester based on voice for underprivileged communities. The application displays various texts onscreen, in sequence from largest to smallest font size. Once a mismatch between the text onscreen and the patient's response happens, a mathematical model adjusts the display to the power eye lens. This study would significantly impact underprivileged communities by giving them access to learning the current condition of their vision [14].

Non-eye-care professionals, to a certain degree, can be trained to perform eye screening tests with accuracy [15]. Sabri *et al.* found this out by conducting tests on 1228 children aged 6-14 years. The study provides helpful information as there may be gaps in providing eye care for a substantial number of children, and such screening methods could be possible.

III. Methodology

This study focused on creating an application that allows the user to conduct an eye assessment using the LogMAR chart for visual acuity and the Ishihara test for the colorblind eye test. This research uses speech-to-text Google API for voice feature recognition. It also has a distance detection to ensure that the users or patients using the system will have a distance of 40cm when doing the eye assessments [16]. The developed system called iGlass is only applicable to Android devices that have Android 5 operating system (OS) and above. This study commenced the development of iGlass and used Android Studio IDE to develop the system.

A. System Design

This study used an academic book published in 2019 entitled "Interaction Design" by Helen Sharp, Jennifer Preece, and Yvonne Rogers [17] for the user experience and user interface design. The study used blue as the primary color of the iGlass application because color blue represents the color of the clinics, and it symbolizes loyalty, strength, wisdom, and trust, according to the reference book. iGlass application also used an ordinary font and a minimalist style to ensure that the design would apply to all ages [18]. The navigation menu is horizontal slide-based UI. According to the study of Choi and Tulu entitled "Effective Use of User Interface and User Experience in a mHealth Application," this type of navigation menu is the fastest. It enabled users to choose their desired item without any error [19]. For the operating system, iGlass supports the Android Lollipop and higher versions. Fig. 1 shows the conceptual framework of the study.

Regarding screen size, iGlass adopted a responsive design manifested to any Android device, whether a phone or a tablet, provided that the mobile device has an Android version of 5.0 (Lollipop) or higher. The voice functionality feature of the application uses Google API, which means it can recognize voice inputs using with or without any peripherals like earphones. iGlass also has a distance detection to ensure that the users or patients is 40 cm away from the mobile device when doing the assessments.

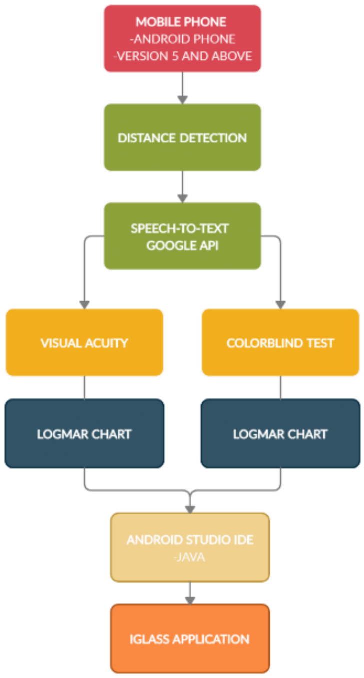
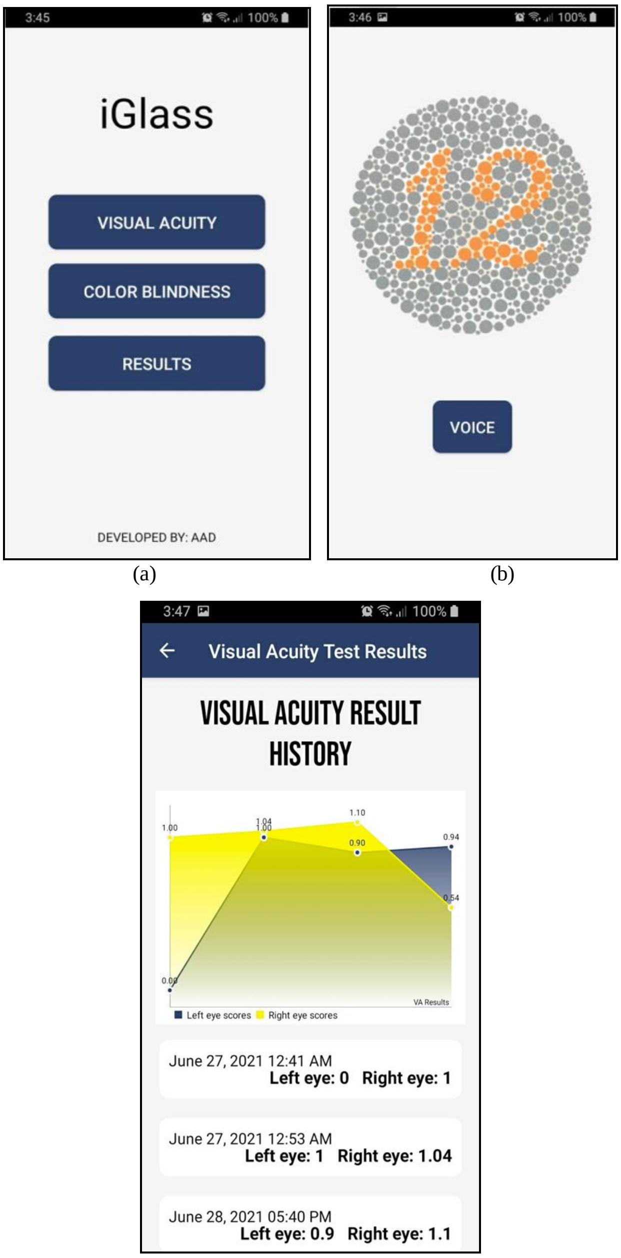


Figure 1. The conceptual framework of the study.

B. Development

This study commenced the development of iGlass and used Android Studio IDE to create the system. The application allows users to change their screen brightness depending on how well they see the image splashed on their screen. The application uses speech-to-text Google API for voice input functionality for the color blindness and visual acuity assessment. Fig. 2 shows the sample user interface of the developed system, iGlass, which starts with the menu, followed by test options (color blindness test or visual acuity test.



(a) (b)

(c)

Figure 2. User interface design of iGlass: a) main menu, b) color blindness assessment, c) eye assessment history.

There are eleven (11) rows of 5 letters each row in LogMAR for visual acuity assessment. In each step, the letter size for every row is decrementing logarithmically by 26%, or 0.1 LogMAR, which begins with a letter-size of 1.0 LogMAR [8]. For the use of LogMAR for visual acuity assessment, the user needs to go through the chart two times until the user commits an error reading a letter (the user is prompted to repeat a particular row three times) so that the application will be able to determine one's visual acuity. Throughout the visual acuity assessment, the application shall guide the user by displaying messages on the screen and voice instructions, such as instructions on what row of letters to read. The LogMAR value of the last line that the user reads successfully shall be the reference for computing the visual acuity. Each optotype, or letter, on the LogMAR chart is worth 0.02 log units. In calculating the LogMAR score of the user, the application shall subtract the product of the number of letters read in the failed line completion and 0.02 to the LogMAR value of the previously completed line.

The color blindness test contains specific assessments for red-green color blindness. The Ishihara test shall be used to assess whether the user is colorblind and falls under the different types of colorblindness. This study uses 25 plates from the Ishihara test, and the user must read the number in the plate to proceed to the next plate. For the scoring method of the Ishihara test, the first plate will be displayed just to know if the user can proceed to do the test. The use of plates 2 to 21 is to determine whether the user has a color vision deficiency. If the user gets eight (8) or more errors on that test, the patient will be classified as colorblind [9]. The plate numbers 22 to 25 are used to classify the type of color deficiency the user has (protanopia, Deuteranopia). The estimated time for the Ishihara test will be 125 seconds for each eye [20]. The application to be developed in this research shall be limited to Android smartphone devices with Android 5.0 (Lollipop) operating systems. This study used Android Studio, an integrated development environment (IDE) for Android operating systems designed specifically for Android development.

C. *Testing*

This study tests the developed application for any errors and problems. There were three tests e conducted. The first is compatibility testing; this is to know if the application is compatible with different hardware. This study used Firebase [21], a software made by Google for compatibility testing. The next test was usability testing and adopted the test cases of the published research paper entitled “The mHealth App Usability Questionnaire (MAUQ): Development and Validation Study” published in 2019 [22]. This study has thirty (30) respondents for the usability testing.

IV. RESULTS AND DISCUSSION

A. *Distance Detection Feature*

The developed system, iGlass, validates screen-to-face distance to determine accuracy at 40 centimeters. The results show that the distance measured at 40cm using a tape measure and the application matches. Therefore, through the Google API included in iGlass, the mobile app can accurately measure the required 40 cm requirement of the Visual Acuity Test as indicated in Table I. The interface of iGlass that shows the detection of the user's distance from the mobile phone while having the assessment is shown in Fig. 3.

TABLE I. COMPARISON OF MEASUREMENT USING TAPE MEASURE VS. THE APPLICATION

Distance test measurement	40cm
Using tape measure	Matched
Using iGlass application	Matched

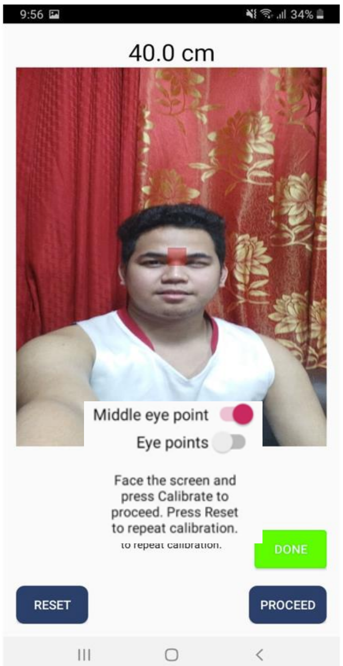


Figure 3. User's distance from the mobile phone.

B. *Traditional Eye Assessment vs. iGlass Application Testing Results*

Traditional eye assessment was compared from the newly developed application through testing with ten (10) participants ages 18-60 years old. The testing was conducted on each of the 2-assessments featured in the mobile application, visual acuity and color blindness. The number of participants was patterned according to the study of Cajita *et al.*, which was approved by John Hopkins institutional review board [23].

- Visual Acuity Test Results

In visual acuity testing, the respondents were assessed using the developed system, iGlass, vis-a-vis with a licensed to practiced optometrist using the standard tools and Snellen chart. The formula for LogMAR score is *row completed minus (0.02×completedLettersInRow)*. The comparative results of visual acuity test are shown in Table II. The first patient had a LogMAR score (iGlass app) for the left eye with 1.04, while the optometrist's findings using the Snellen chart was 20/200. Among the patients who were the respondents for this test, only one had a mismatch with the iGlass results and results from the optometrist. A mismatch happens when the patient's answer is incorrect. Patient number 4's right eye had a LogMAR score of 0.46, while the optometrist measured 20/63. One out of five respondents had a mismatched, leading to 100% accuracy for the left eye and 80% accuracy for the right eye based on this testing. The results indicate that the iGlass application was able to measure the patients' visual acuity accurately.

Snellen charts measure visual acuity by row, whereas LogMAR charts consider the individual letters in a row. The reference table comparing the two visual acuity chart's scores is shown in Table III. Scoring for visual acuity test is consist of 11 stages, each stage consists of 5 letters, and each letter has a corresponding value or 0.02. Each time the user gets the correct letter answer, a score of 0.02 will be subtracted to his/her score until he commits three (3) errors. For example, patient number 2 on Table II has a LogMAR score of 0.72 for both the left and right eye. The patient made a mistake on the fourth row (Row 0.70), so the system takes 0.80 as the value for the row completed in the formula. The system lets the patient finish the particular row where they made a mistake, then takes the number of letters in that row which the patient got it correctly. For this instance, patient number 4 got four (4) letters correct in the row; multiply that by 0.02, which is the value of each optotype in the formula, you get 0.08. Then, we subtract 0.08 to 0.80 to get 0.72, which is the LogMAR score.

TABLE II. COMPARISON TABLE OF VISUAL ACUITY ASSESSMENT RESULTS

Patient Age	**iGlass (LogMAR scores)**		**Snellen Chart (Traditional)**		**Remarks**
	Left Eye	Right Eye	Left Eye	Right Eye	
33	1.04	1.02	20/200	20/200	Matched
55	0.72	0.72	20/100	20/100	Matched
19	0.14	0.12	20/25	20/25	Matched
54	0.72	0.46	20/100	20/63	Mismatched
19	0.62	0.82	20/80	20/125	Matched

TABLE III. VISUAL ACUITY COMPARATIVE CHART BETWEEN LOGMAR AND SNELLEN TESTING RESULTS

LogMAR	**Snellen**
0.00	20/20
0.10	20/25
0.20	20/32
0.30	20/40
0.40	20/50
0.50	20/63
0.60	20/80
0.70	20/100
0.80	20/125
0.90	20/160
1.00	20/200
1.10	20/400

C. *Color Blindness Test Results*

In this phase, the five (5) respondents for color blindness assessment were evaluated using the developed iGlass system vis-a-vis with a licensed to practiced optometrist and their tools. The testing was conducted in a normal lit room. Comparing the color blindness assessments results while using the iGlass application and the traditional assessment is shown in Table IV. The results show 100 percent similarities between using the iGlass application and the traditional color blindness assessment. Therefore, the color blindness assessment feature of the iGlass application is accurate and reliable as a screening test for color deficiency. Note that "NCB" means NOT COLOR BLIND, Protanopia means you have a red color deficiency, and Deuteranopia means you have a green color deficiency [24].

TABLE IV. COLOR BLINDNESS ASSESSMENTS RESULTS

Patient Age	iGlass (LogMAR scores)	Snellen Chart (Traditional)	Remarks
	Left and Right Eye	Left Eye Right Eye	
33	NCB	NCB	Matched
55	NCB	NCB	Matched
19	PROTANOPIA	PROTANOPIA	Matched
54	DEUTERANOPIA	DEUTERANOPIA	Matched
19	NCB	NCB	Matched

D. Usability Test

In this usability testing, there were thirty (30) participants used the developed system, iGlass and surveyed to answer the usability questionnaire adopted from the study of Zhou *et al.* or the mHealth App Usability Questionnaire (MAUQ) [22]. The survey questionnaire comprises eight (8) questions with a 5-point scale (strongly disagree, disagree, neutral, agree, and strongly agree).

The usability testing corresponds to the ease of use and satisfaction of the thirty (30) participants who participated in this study are shown in Table V. It shows that 100% of the participants strongly agreed that the mobile application was easy to use. It was easy for them to learn how to use the app and all the information; the application was well organized, making it easier to find the information they needed. While there were 96.7% of the total number of participants strongly agree, and 3.3% of the participants agree with the following statements: they liked the interface of the application, they felt comfortable in using the application in social settings, that they would use the application again and they are satisfied with the application. The 93.3% of the participants strongly agreed that the amount of time involved in using the application has fitted for them. In comparison, there are 3.3% who gave a good or "Agree" evaluation.

TABLE V. USABILITY RESULT -EASE OF USE AND SATISFACTION

Survey Question	Agree	Strongly Agree	Mean
1. The app was easy to use.	0	100%	5
2. It was easy for me to learn how to use the app	0	100%	5
3. I like the interface of the app.	3.30%	96.70%	4.97
4. The information in the app was well organized, so I could easily find the information I needed.	0	100%	5
5. I feel comfortable using this app in social settings.	3.30%	96.70%	4.97
6. The amount of time involved in using this app has fitted me.	6.70%	93.30%	4.93
7. I would use this app again.	3.30%	96.70%	4.97
8. Overall, I am satisfied with this app.	3.30%	96.70%	4.97

The usability testing for the system's organization design is shown in Table VI. It shows that most of the survey respondents answered "Strongly Agree" resulted to 96.7%. In comparison, there are 6.7% responded that they agreed with survey question that mHealth application would provide an acceptable way to receive health care services, the interface of the application allows them to use all of the function available on the application and that the application has all of the function and capabilities they expected for it to have.

There are 93.3% of the participants gave "Strongly Agree" while 6.7% agree with survey questions that whenever they made a mistake in using the application, they could easily and quickly recover, that the application acknowledged and provided information to let the user know about the progress of their action and that the navigation was consistent when moving between the screens. No usability result that falls on strongly disagree, disagree and neutral.

TABLE VI. USABILITY RESULT - SYSTEM INFORMATION ORGANIZATION

Survey Question	Agree	Strongly Agree	Mean
1. Whenever I made a mistake using the app, I could recover easily and quickly.	6.70%	93.30%	4.93
2. This mHealth app provided an acceptable way to receive health care services.	3.30%	96.70%	4.97
3. The app acknowledged and provided information to let me know the progress of my action.	6.70%	93.3%	4.93
4. The navigation was consistent when moving between screens.	6.70%	93.30%	4.93
5. The app's interface allowed me to use all the functions (such as entering information, responding to reminders, viewing information) offered by the app.	6.70%	93.30%	4.97
6. This app has all the functions and capabilities I expect it to have.	3.30%	96.70%	4.97
TOTAL	5.0%	95.0%	4.96

The usability result for usefulness of the application is shown in Table VII. The results show that there are 96.7% of participants said that they strongly agreed while 3.3% said that they agree with the following statements: that the application would be useful for their health and well-being, that the application helps them improve their access to health care services, and that it helped them to manage their health effectively.

TABLE VII. USABILITY RESULT - USEFULNESS

Survey Question	Agree	Strongly Agree	Mean
1. The app would be helpful for my health and well-being.	3.3%	96.7%	4.97
2. The app improved my access to health care services.	3.3%	96.7%	4.97
3. The app helped me manage my health effectively.	3.3%	96.7%	4.97
TOTAL	3.3%	96.7%	4.97

E. Compatibility Test

Firebase Test Lab, a cloud-based application platform used to test the compatibility of a system application with the different application programming interface (API) levels offered by Android devices, was used in compatibility testing. The iGlass mobile application, was tested in ten (10) different API levels. The API level 21 (Android 5.0) up to API level 30 (Android 11) tests showed that the developed system would run smoothly and successfully on the ten (10) API level, from Android versions 5 to 11 as shown in Table VIII. The iGlass application is said to be compatible with the Android operating system Lollipop and higher versions. Firebase Test Lab is a Beta of Google [24].

TABLE VIII. COMPATIBILITY TESTING RESULT OF IGLASS

API Level	Android Version	Device Name	Results
21	Android 5.0 (Lollipop)	Nexus 9	Passed
22	Android 5.1 (Lollipop)	Nexus 7 (2012)	Passed
23	Android 6 (Marshmallow)	LG-X230	Passed
24	Android 7.0 (Nougat)	VS988	Passed
25	Android 7.1 (Nougat)	PH-1	Passed
26	Android 8.0.0 (Oreo)	H8314	Passed
27	Android 8.1.0 (Oreo)	ASUS_X00TD	Passed
28	Android 9 (Pie)	SM-T720	Passed
29	Android 10	SM-A105FN	Passed
30	Android 11	Pixel 5e	Passed

The manual compatibility test result using an emulator with different API levels is compared to the online Firebase Test Lab as shown in Table IX. The check marked on Table IX means a passed result, and the developed application is fully functional to the different API levels. The result shows that API level 21 to 30 is compatible with the iGlass application. The comparison between the two tests, manual testing and using the Firebase Test Lab, shows the same result for all the API levels means that the application is compatible with the ten (10) API levels.

TABLE IX. COMPATIBILITY TESTING RESULT OF IGLASS

iGlass Functions	API Levels									
	21	22	23	24	25	26	27	28	29	30
Color Blindness Test	√	√	√	√	√	√	√	√	√	√
Visual Acuity Test	√	√	√	√	√	√	√	√	√	√
Result History	√	√	√	√	√	√	√	√	√	√
Voice Recognition	√	√	√	√	√	√	√	√	√	√
Distance Measurement	√	√	√	√	√	√	√	√	√	√

V. CONCLUSION AND RECOMMENDATION

This study aims to develop a mobile application for virtual eye assessments called iGlass. The application is intended for eye assessments involving visual acuity and color blindness. Moreover, the application also provides a history log where users can see assessment results and chart the changes in their eye condition over time. A mobile application for visual acuity designed the visual acuity chart to be used and integrated into the mobile application. The testing results for the visual acuity show that the application using the LogMAR chart effectively measured the visual acuity of the users with 90% accuracy upon comparison with results of the test using traditional methods – that is, with the optometrist conducting the assessment. The test result was accurate as tested with actual patients using the developed mobile application.

The mobile application design for color blindness used Ishihara plates as they are the most renowned and reliable instruments for measuring color deficiency. The results of the color blindness test show that the application with the use of Ishihara plate was effective in measuring if the user is colorblind or not with a 100% accuracy rate, upon comparison with results of the test using traditional methods – that is with the optometrist conducting the assessment. The test result was accurate as of the trial with actual patients using iGlass mobile application.

Based on the compatibility test result, which uses Firebase Test lab, a cloud-based platform that Google developed, and manual testing for the compatibility test to verify the results given by the Firebase. It shows that the iGlass application is compatible and can run smoothly with an Android operating system version 5 (Lollipop) and higher.

The usability and functionality results use the adopted instrument from the study entitled the mHealth App Usability Questionnaire (MAUQ). Most of the respondents marked each function and feature with "Agree and, Strongly Agree" survey answers. All usability tests passed the functionality test, which demonstrates that the application has met all the functional requirements of the users. The average mean for the usability test result is 4.6666. Based on the user acceptance testing result (UAT), optometrists gave a "passed" remark for all functions and features of the mobile application. The passing statement indicates that the iGlass application is medically accepted. Users and the optometrist were also satisfied with the user interface and the ease of access. All the suggestions and recommendations stakeholders mentioned are taken note of and shall be considered part of the enhancements included in the application.

CONFLICT OF INTEREST

This research paper presentation and registration was funded by Mapua University. All authors declare that they have no conflicts of interest.

AUTHOR CONTRIBUTIONS

Ms. Samonte supervised the whole research development and took the lead in writing the manuscript. Mr. Abellon established the theoretical formalism and transfer it to technological development. Mr. Ariola and Ms. Danao performed the simulations and testing. All authors provided critical feedback and helped shape the research, analysis, and manuscript.

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