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EYE-R : Augmented Reality as Mobile Based Helper Application for Colorblinds

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Abstract: The ability to identify color is a basic ability for a human to live easily. Unfortunately not all humans have normal sight, there are some humans who have an eye disorder called color blindness. Color blindness is an eye disorder that affects color perception of the affected person in everyday life, therefore the person that has color blindness needs a device to help them to identify some colors. In the medical world, the usage of Augmented Reality is still limited for education for medical practitioners, so the application of AR as a tool to help patients is still considered to be minimal. Augmented Reality as a Mobile Based Colorblind Helper Research aims to find out how effective a color detection system using AR as a tool to help the colorblinds identify color in an application called "EYE-R". The research method employed in the research and development of this application is the Waterfall method that involves the stages of Requirements, Design, Programming, Testing, and Implementation. The main feature of "EYE-R" is chosen using a survey which is Real Time Color Detection which is developed using the Unity engine and implemented using Android. The research results show that the majority of users can operate the Real Time Color Detection system accurately. The user satisfaction results recorded using *USE Questionnaire* shows that the EYE-R *Real Time* Color Detection system really helps users' daily lives and can be used very well.

Keywords: Android; Augmented Reality; Color Blindness; Mobile Development; Unity Engine

INTRODUCTION

Color Vision Deficiency (CVD) or commonly known as color blindness is a disorder of the eye that interferes with the patient's ability to distinguish colors that cause obstacles to his daily life (Alam et al., 2022). Color blindness is a condition in which the cone in the eye is affected, which can be hereditary or acquired and is considered a moderate disability that affects as much as 8.5% of the world's population and is generally present in young children (Cesar et al., 2020). Red-green color blindness is a common trait that affects at least 10% of men and only 1% of women (Basta & Pandya, 2022). Not a few of the children who have reached the age of 18 months but still have difficulty in recognizing basic colors, for example when the child is ordered to classify and name the colors pointed by the teacher (Nityanasari, 2020). In a study conducted in 11 elementary schools located in Badung Regency, a prevalence of 2% of 900 samples with color blindness was found, with a higher gene frequency in the male gender (Karolina et al., 2019). In the past 3 years, the development of digital innovation in every industrial sector has grown rapidly, including the health sector which is directly affected by digitalization. Some of the technologies that can be developed to help color blind patients distinguish color shades include Augmented Reality / AR, Android Apps, color-changing filters, and image processing (Baswaraju

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Swathi et al., 2020; Cesar et al., 2020.; Gurumurthy et al., 2019; Li et al., 2021; M. A. Martínez-Domingo et al., 2019; M. Á. Martínez-Domingo et al., 2020). Of the many technologies mentioned, Augmented Reality or AR is one of the modern technologies that is slowly increasing its use for entertainment to medical needs (Aydındoğan et al., 2021). Augmented reality is a type of application or experience that aims to integrate and expand the user's world digitally in real time by adding digital information layers (Arena et al., 2022).

In general, people with color blindness have deficiencies in the acceptance of certain light spectra, causing differences in perception in distinguishing colors (M. A. Martínez-Domingo et al., 2019). Therefore, a system is needed where people with color blindness can be helped in distinguishing certain shades of color in everyday life, because in general, people with color blindness have deficiencies in distinguishing color shades (Gurumurthy et al., 2019).

Based on research conducted by Zanudin Husain in 2020, the development of a simple Android-based color blind patient aid application can be carried out using training data to recognize several types of colors that are difficult for blind patients to recognize. color. The difference between this research and my research is that my research uses a real time detection system (Husain et al., 2020).

In subsequent research, Julio Cesar Ponce Gallegos et al designed a system that can recognize the color of an object and then assign a color label to the scanned object. The designed system can also paint new colors on scanned objects to make it easier for color blind patients to recognize colors. The difference between this research and my research is that there is no tracking of scanned objects (Cesar et al., 2020)

From the data that has been exposed above regarding the needs of people with color blindness, this research aims to develop an AR system combined with smartphone devices that the majority of people already have so that the use of applications can be used in everyday life and in the long term. Based on previous research studies, the use of tools that are easy to use in everyday life has proven to be very helpful for people with total or partial color blindness. By implementing AR technology on mobile devices, aids for people with color blindness can become more affordable and can facilitate the daily lives of patients with color blindness. With the "EYE-R" application, users with color blindness can also more easily distinguish the colors of certain objects in their daily lives. Thus this application research can be a positive impact in providing the first step in the world of medical technology to facilitate the accessibility of color blind patients both partial and total in identifying colors.

LITERATURE REVIEW

After a research on a few studies that has been carried out in the last 5 years, there are a few methods that implement Augmented Reality to be a helper for colorblinds. Based on research conducted by Zanudin Husain in 2020, the development of a simple Android-based color blind patient aid application can be carried out using training data to recognize several types of colors that are difficult for blind patients to recognize. Color (Husain et al., 2020). In subsequent research conducted in the past 5 years, other studies have discovered other methods such as A system that tracks colored object (Cesar et al., 2020), color pattern changer (Gurumurthy et al., 2019), and outlining object of color using method called saliency (J. Li et al., 2020).

Based on research conducted by Tongkeng Li which discusses the use of Augmented Reality in Ophthalmology (a study that studies eye diseases). In their discussion, they provided suggestions regarding systems used to scan colors, systems that are easy to use, and also compared the advantages of smartphone-based AR systems when compared to devices that are more difficult to reach such as Google Glass, Microsoft HoloLens and others. In the discussion there are also suggestions regarding the use of smartphone-based AR through color replacement features and displaying information based on the severity or type of the user's color blindness. (T. Li et al., 2021).

In a study conducted by Ribeiro, the usage of multiple methods is used for different types of colorblindness (Ribeiro & Gomes, 2019).The methods used are LMS based methods that affect anomalous trichromacy by increasing the values of L,M,S depending on the protan, deutan, and tritan types of colorblinds. Therefore, this method is perceived to be consistent, however, by overly increasing

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the value of L will change all the RGB colors of the pixels so the natural color will be preserved only if L increased by only a small number.

METHOD

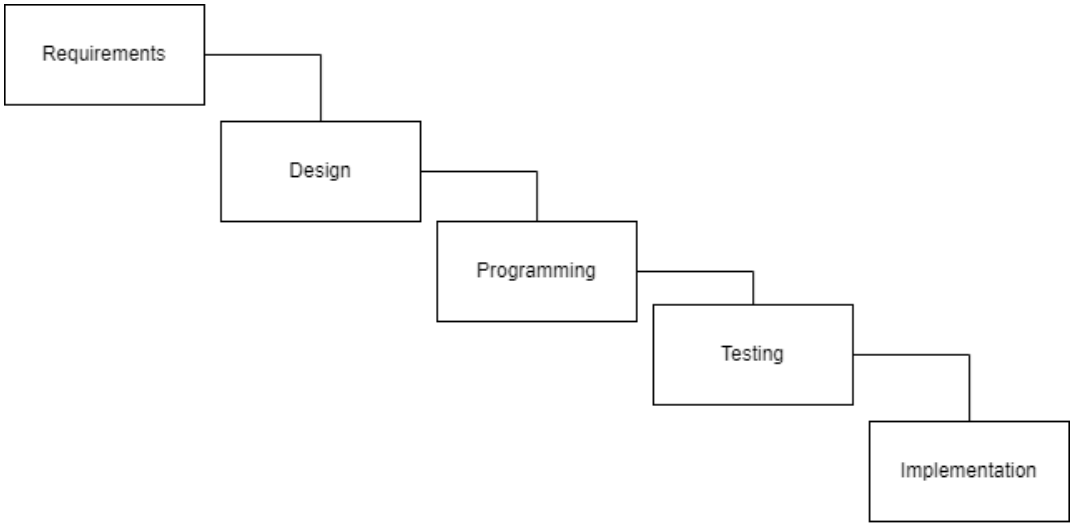

Fig. 1 Waterfall Method Process

Figure 1 is a picture of the stages of the Waterfall research methodology process starting from the Requirements stage to determine application features and then enter the Design stage, continued to the Programming stage to design applications based on design, the next stage is the Testing stage which is carried out with black box testing and finally the Implementation stage which utilizes the USE Questionnaire to determine the usability of the research application (Elvis Pawan et al., 2021).

Requirements Stage

This Requirements stage is carried out by providing a questionnaire "Color Blind Helper Application Feature Surveyor" which contains questions about each respondent's use of smartphone, how severe the respondent's color blindness is, and choices regarding which types of features would be suitable to be implemented in applications that use technology. Augmented Reality. The questions are chosen based on some of other researchers' methods/features from literature review. The following are the results of a survey of the main features of the "EYE-R" application

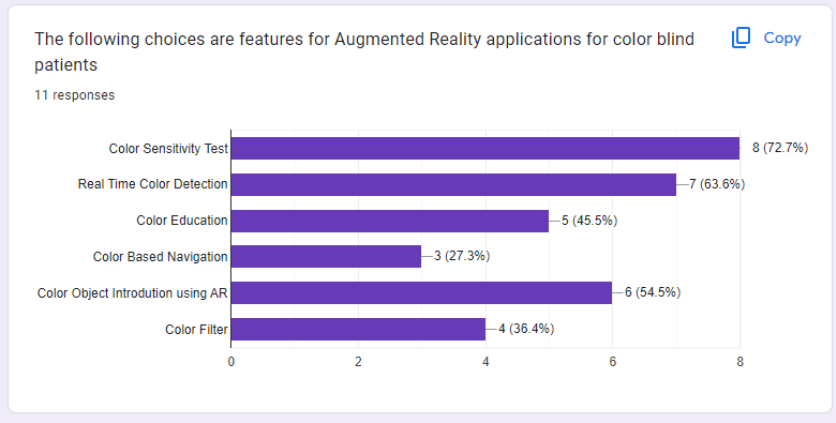

Fig. 2 Survey Result

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From the collected data, an analysis was conducted to formulate which features are suitable to be implemented in the application, additional features required, and other technical matters. Although the highest survey result was the Color Sensitivity Test, the researchers decided that the Real Time Color Detection feature was the most appropriate feature to be implemented as the primary feature and the Color Sensitivity Test emerged as the secondary feature.

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Design Stage

At the Design stage, the initial form of the application is designed which is then used as a guide when entering the programming stage.

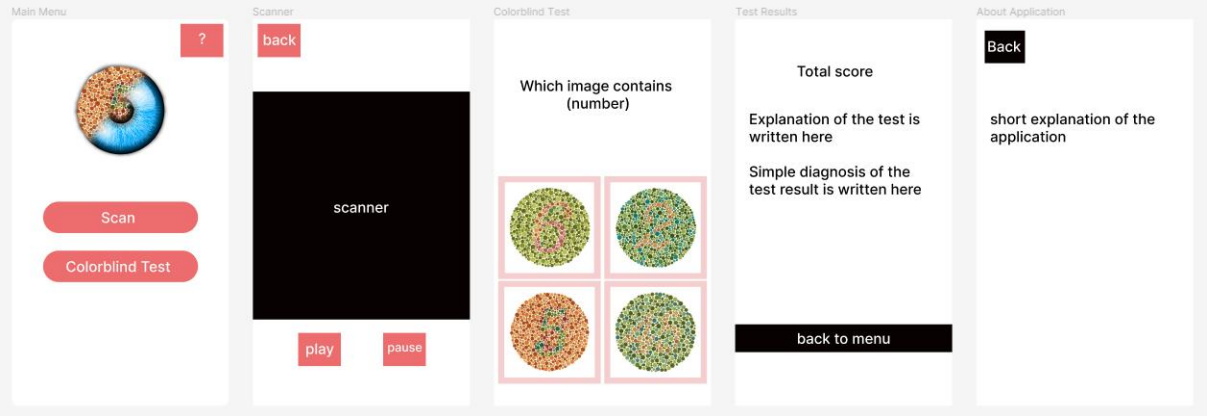

Fig. 3 Early Application Design

The UI design process was carried out using Figma with the aim of making it easier to visualize the functionality of the buttons that will be used. Apart from designing the initial UI image, at this stage a flowchart is also created which aims to design the steps for using the application. Finally, at this design stage, a VTOC diagram is also created to map out what content will be included in the application

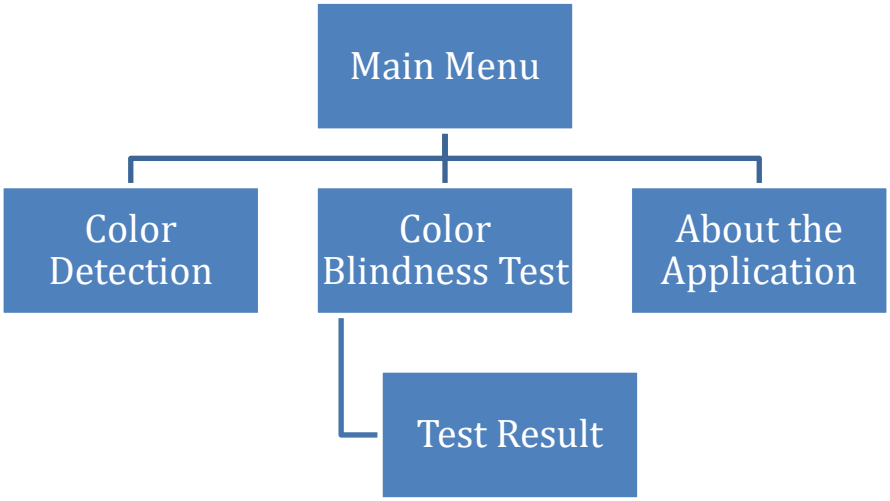

Fig. 4 VTOC Diagram

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Programming Stage

At this Programming stage, code writing begins and starts building applications using Unity software with guidance from the diagrams and initial designs that have been made at the Design stage. The first step in writing code and design is to determine the plugin that will be included in the application design. In this case, the plugin used is "OpenCV for Unity" which provides a means of making a color detection scanner. At the programming stage, early stage testing is also carried out in order to minimize bugs or problems when entering the Testing stage.

Testing Stage

The testing stage is carried out using the black box testing method, where an object scanning experiment is carried out to detect color, which is divided into two stages.

The first stage of testing was carried out using the Unity editor system which uses a webcam camera as a smartphone camera simulation. The second stage is carried out directly using an Android type smartphone. This black box testing is carried out with the aim of proving that the application system functionality can run well. The following table is the scenario for the black box testing.

Table 1. *Black Box Testing*

No	Testing Scenario	Result	
		Success	Failed
1	In the color detection menu, system can identify 3 different colors		
2	In the color detection menu, system can trace and labels the object in front of the camera		
3	In the colorblind test menu, system always shows the question randomly		
4	In the main menu, if the user presses “Mulai Scan” system immediately open the color detection menu and immediately starts scanning		
5	In the test result menu, system accurately displays user’s grade		

Implementation Stage

At this stage, the application was tested on color blind users and created a questionnaire containing 13 statements based on the USE Questionnaire which was designed to assess the Usefulness, Satisfaction, Ease of Learning and Easy of Use for users when using the system (Lund, 2001). USE Questionnaires are measured using a Likert scale with a scoring system of 1 to 7, where number 1 indicates the lowest value and number 7 indicates the highest value. After the questionnaire is filled in, the results of the questionnaire are used to calculate the usability percentage which will be compared with the standard feasibility values in the table.

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Table 2. Questionnaire Statements

Factor	Number	Statement
Usefulness	1	This application helps my productivity
	2	This application is useful
	3	It makes my task easier to get done
	4	It meets my needs
	5	It does everything I would expect it to do
Ease of Use	6	It is easy to use
	7	It is user friendly
	8	Using it is effortless
	9	I can use it without written instructions
	10	I can use it successfully everytime
Ease of Learning	11	It is easy to learn to use it
Satisfaction	12	I would recommend it to a friend
	13	I feel the need to have it

To calculate the percentage of application usage level, the formula for calculating the usability percentage based on the USE Questionnaire results is used as follows (Ningtiyas et al., 2021):

$$k(\%) = \frac{s \times y \times d}{s \times y \times ha} \times 100\% \quad (1)$$

$k(\%)$: usability percentage
s : scale score
y : total statements
d : total respondents
ha : maximum score

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The percentage data obtained from calculating the Usability level will later determine how feasible the application is based on the feasibility category table in table 4.

Table 3. Usability Category

Pecentage (%)	Classification
< 20	Very Unfeasible
21 - 40	Not Feasible
41 - 60	Decent
61 - 80	Proper
81 - 100	Very Proper

RESULT

As mentioned before, the output of this research is an application that could detect the main color of an object after the object is scanned using a built-in camera in the user's smartphone to facilitate color blind users in distinguishing colors. The other output is to also create a simple colorblind test to help diagnose the severity of its users where users perform a color blindness test using Ishihara plates. To test the usability of the application, black box method were used to determine if the application is suitable for implementation. To evaluate the usability of the final application, a survey was conducted using statements from USE Questionnaire which then calculated to find the usability percentage of the application.

Final Application

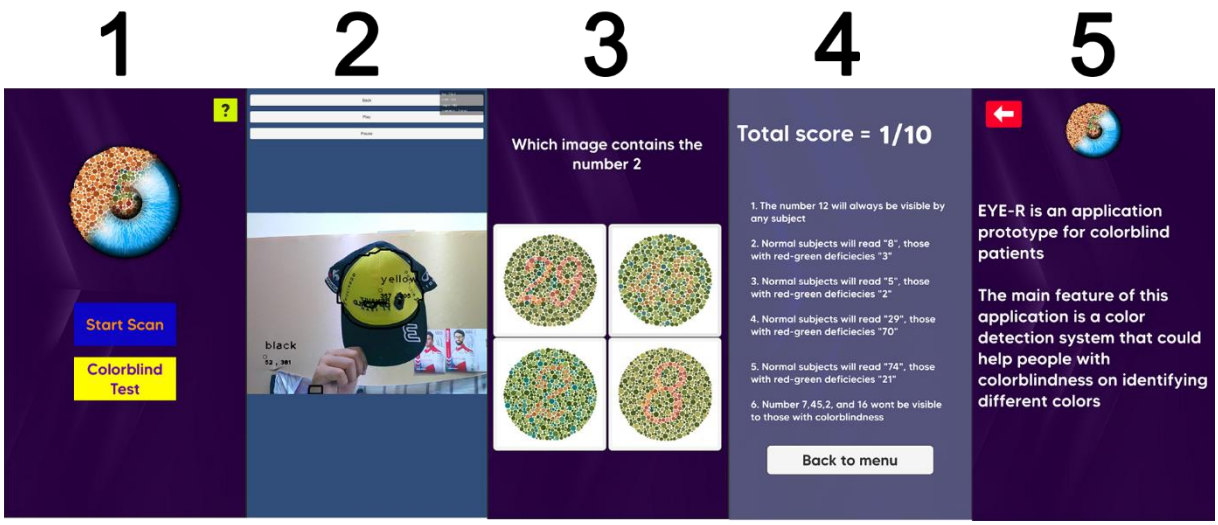

Fig. 5 All menu inside the application

In figure 5, all the menus in the application are displayed. Number 1 shows the main menu which contains 3 buttons, namely the "Start Scan" button "Color Blind Test" and the "?" which is basically a button that will display application information.

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Number 2 shows the Color Detection menu when it is activated. As shown in figure 5, the user only needs to point the camera at the target object.
Number 3 shows the Colorblindness Test menu when being used by the user. In this test, users are given 10 questions which are always displayed in random order so that users cannot memorize the answers. The use of text-based questions here is also related to menu number 4
Number 4 is the score recording menu where users who have completed the previous 10 question test are given their test results, then given a complete explanation regarding the user's type of color blindness based on the user's performance on the test (*Ishihara Instructions*, n.d.)
Number 5 is the application menu which contains an explanation of this application

Black Box Testing

After the programming was completed, the testing stage was carried out using the black box testing method to test whether the color detection system and color blindness test menu were ready to be implemented to general respondents.

Table 4. *Black Box Testing*

No	Testing Scenario	Result	
		Success	Failed
1	In the color detection menu, system can identify 3 different colors	v	
2	In the color detection menu, system can trace and labels the object in front of the camera	v	
3	In the colorblind test menu, system always shows the question randomly	v	
4	In the main menu, if the user presses “Mulai Scan” system immediately open the color detection menu and immediately starts scanning	v	
5	In the test result menu, system accurately displays user’s grade	v	

Implementation and Usability Survey

Application implementation and survey was carried out on 7 users who have color blindness. All users who took part in this implementation filled out a 13 statements questionnaire which was created based on the USE Questionnaire and filled in using a Likert scale. The 13 statements consist of 5 statements for the usability aspect, 5 for the ease of use aspect, 1 regarding the ease of learning the application, and finally 2 statements for the user satisfaction aspect of the application. The following is a table showing the respondents who participated in the implementation process of this research.

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Table 5. Implementation Participants

Responden	Gender	Color Blindness Type
Responden 1	Male	Partial
Responden 2	Male	Partial
Responden 3	Male	Partial
Responden 4	Male	Partial
Responden 5	Male	Partial
Responden 6	Male	Partial
Responden 7	Male	Partial

Before filling out the questionnaire, respondents must try the application so they can understand how to use all its features. The questionnaire statements filled in by respondents referring to the statements in the USE Questionnaire tool. From this tool, 13 statements were made related to the 4 USE Questionnaire factors, namely usefulness, satisfaction, ease of use, and ease of learning

Table 6. Final Questionnaire Result

Factor	Number	Statement	Score
Usefulness	1	This application helps my productivity	7
	2	This application is useful	6.8
	3	It makes my task easier to get done	6.7
	4	It meets my needs	6.8
	5	It does everything I would expect it to do	6.7
Total Usefulness			34
Ease of Use	6	It is easy to use	7
	7	It is user friendly	6.8
	8	Using it is effortless	7
	9	I can use it without written instructions	6.8

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	10	I can use it successfully every time	7
Total Ease of Use			34.6
Ease of Learning	11	It is easy to learn to use it	7
Total Ease of Learning			7
Satisfaction	12	I would recommend it to a friend	6.8
	13	I feel the need to have it	6.8
Total Satisfaction			13.6
Total Overall			89.2

After recapitulating the value of each factor and the entire questionnaire, the percentage of Usability level for each factor and the overall questionnaire results can be calculated. The first aspect whose value will be calculated is the Usefulness aspect.

$$k1 = \frac{34 \times 7}{7 \times 5 \times 7} \times 100\% = 97.1\% \quad (2)$$

Next, is the Ease of Use aspect

$$k2 = \frac{34.6 \times 7}{7 \times 5 \times 7} \times 100\% = 98.8\% \quad (3)$$

Next is the Ease of Learning aspect

$$k3 = \frac{7 \times 7}{7 \times 1 \times 7} \times 100\% = 100\% \quad (4)$$

Last aspect is Satisfaction

$$k4 = \frac{13.6 \times 7}{7 \times 2 \times 7} \times 100\% = 97.1\% \quad (5)$$

Finally, it is necessary to calculate the overall USE Questionnaire results value

$$kTotal = \frac{89.2 \times 7}{7 \times 13 \times 7} \times 100\% = 98\% \quad (6)$$

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DISCUSSIONS

In After conducting all of the test and survey session, it can be seen that when the application is being used, the system appears to be successfully fulfill all of the targets of the research, with the color detection system successfully draws outline of all of the object of color in front of the camera and also successfully display the main color of the object, and the scoring system successfully display user's score after completing the colorblind test. Both of those results are considered to be an indication that the system are working properly. The only problem that the system encountered is when the application is in use, it could overheat the user's phone which could be resolved by stopping the application manually from the smartphone system.

The result of the survey also shows that users are satisfied with the performance of the application and based on each of the calculation results, all of the USE Questionnaire factors used as consideration shows that the application is very proper. The results of recapitulation and calculation of scores from questionnaires created using the USE Questionnaire method show that it can be concluded that the "EYE-R" application has a very feasible usability level with the Usefulness factor which has a percentage of 97.1% which indicates that this application can provide very significant help for people with partial or total color blindness, the Ease of Use factor with a percentage of 98. 8% shows that the majority of respondents feel it will be very easy to operate "EYE-R" in their daily lives, the Ease of Learning factor with 100% final percentage which shows that the features of "EYE-R" can be quickly adopted by users, the Satisfaction factor with a percentage of 97.1% shows that the respondents are feeling satisfied after using the application.

CONCLUSION

An efficient color blindness helper application can make life easier for people with color blindness in carrying out their daily lives. The main feature in the "EYE-R" application in the form of color detection while providing outlines for objects whose colors can be detected is proven to function properly and can satisfy its users with an application usage system that is proven to be simple and easy to understand by its users. However, the implementation of the color detection system can be improved to be more accurate in drawing the object's final outline. The color blind test system also proven to be accurate and can help users in determining their colorblindness type, however some users felt that the colorblindness test results can display more results. Moreover, after calculating the final survey results, it is concluded that with the high level of usability of the three factors mentioned earlier, users feel satisfied after using the "EYE-R" application and with a total percentage of 98%, it can be concluded that with the USE Questionnaire method, respondents' assessment of the usability of the "EYE-R" application falls into a very feasible level.

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