Mobile Game "Color in Life" Development for Dichromatism Color Blind

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***Abstract*— The purpose of this research was to escalate players' knowledge on color blindness by designing an educational video game which design was oriented to dichromatism color blind. The topic selection was based on the lack of players' deeper knowledge on color blindness. The graphic and gameplay selection on this research was adjusted to the chosen color blind category. Research methods were conducted by analysis, development, and evaluation. Analysis was done by questionnaire. Development was done by game design document, UML, storyboard, and was implemented using Unity. Evaluation on 35 players, which are 32 with normal eyes and 3 with color blindness, was done by two approaches, which are t-test and questionnaire. The result of t-test was t(34) = -7.704, p < 0.05 and Enjoyment score on CEGE is 0.763 for normal eyes and 0.651 for colorblind. To conclude, there was an improvement on knowledge from the video game and the design wasenjoyable.**

Keywords— color blind, educational game, game development, mobile game

I. INTRODUCTION

About 8% of men and 0.1% women in the world are not able to see color perfectly [12]. This situation is called *color vision deficiency* (CVD) or usually called as color blind. The latter, however, is a little misleading as these people still see colors, contrary to what those who don't understand CVD believe. The problem is those who don't understand CVD are stilla lot, which leads to the disregarding of the defected.

This problem also found in the gaming world. Most of the CVD are made up of the red-green color defected [5], yet in games green and red are usually used to identify own team and the opposing team respectively. This might lead to confusion for thedefected.

Some game developers applied screen filter according to each type of color blind, though sadly this method is not as effective and might even be more confusing [13]. Other developers allowed player to customize the color combination while the others usedicons to avoid colorization confusion.

From the situation described above, it can be identified that there is lack of knowledge and CVD in the society. The defected also have a hard time while playing video game and at the same time the adaptations done by game developers for CVD have not been effective yet.

Due to the problems identified earlier, authors decided to develop a game oriented to specifically dichromatic that in hypothesis can help raise knowledge and awareness of the players regarding CVD through video game and can be enjoyable for both defected and non-defected.

II. METHOD

The development process was done with waterfall approach and authors conducted the research through literature review, interview, and survey.

A. Literature Review

Literature entries include books, web articles, journal articles, and previous researches. Research was done through this method to gather information regarding CVD, type of game, and evaluation method. Color vision deficiency (CVD; also known as color blind) is a condition where deficiencies are found in any of the photoreceptor cone cell – namely *long-wavelength*(L) *cone*, *middle-wavelength*(M) *cone*, and *short-wavelength*(S) *cone*. This deficiency is caused by gene mutation, although there could be cases caused by medication or accident.

There are three types of CVD according to its severity: *anomalous trichromacy*, *dichromacy*, and *monochromacy*. Anomalous trichromacy is caused by the presence of *anomalous photopigment*, that is a pigment that underwent chemical change due to anomaly in the light intensity. Dichromacy can be caused by the absent of L cone and replaced by M cone, the absent of M cone and replaced by L cone, or mutation in one or both S cone. On the other hand, Monochromacy happened if all cone cell is absent.

CVD can also be divided according to the position of the mutation. *Protan* is for L cone, *deuteran* is for M cone, and *tritan* is for S cone. The first two are usually classified as red-green color blind while the latter is blue-yellow color blind [5].

One of a CVD screening test that can differentiate the type is *Farnsworth-Munsell 100 Hue Test* (FM 100-Hue), which was done by arranging a hundred similarly colored blocks. This test, however, was claimed lengthy and complicated by Bowman and Cameron hence in 1982 they suggested an alternative called *Farnsworth-Munsell Dichotomous D-15 Test* (Panel D-15), which the differences with FM 100-Hue including it only consists of 16 color blocks including the pivot and can only detect moderate and severe CVD [2].

This method was calculated by dividing the *total color difference score* (TCDS) obtained from the actual test with the

perfect TCDS to get the *color confusion index* (c-index). TCDS itself is the sum of the CIE 1976 (L* a* b*) (also known as CIELAB) formula for ΔE [1].

The game made through this research is a visual novel educational game. Educational games are created to help people understand certain concepts, usually in the form of board game, card game, or video game [10]. Adventure game is a game genre that involved interactive story about a protagonist character played by players, which includes storytelling, exploration, puzzle solving, and challenge with concept [4]. One of the sub-genre called *visual novel* that is originated from Japan. Games that fell in this sub-genre present the information by adapting it into strong story with dramatic tension along with interesting character and interactive puzzle and are easy to operate; which help the learning process [7].

Core Element of Gaming Experience (CEGE) is a model used to measure gaming experience of a video game found by Eduardo Héctor Calvillo-Gámez in 2009. The CEGE can be used to calculate 10 elements of the game, which are Frustration, Enjoyment, CEGE, Puppetry, Control, Facilitator, Ownership, Video Game, Environment, and Gameplay. Frustration and Enjoyment indicates the level of frustration and enjoyment the players felt while finishing the game. Environment indicates the pleasure the players felt from the graphics and audio used in the game. Gameplay indicates the pleasure the players felt from the mechanic and scenario implemented in the game. Lastly, CEGE indicates the pleasure the players felt with the whole elements of the game [3].

Through literature review, there are at minimal of three related research found. The first one is Dodo Game, the second is GLUB, and the last one is MoCHA.

Dodo's Catching Adventure is a game consisted of CVD screening test for young children as the widely used Ishihara Test requires more advanced verbal or cognitive skill. The research resulted in the potential of the game to be a new clinical tool for CVD test [8].

GLUBS are games based on molecular mechanisms that take place in biological systems with the goal is to discover the correct interactions between molecular components. The result of the research is that information discovered by various biological experiments can be used to create games that are educational as well entertaining, interesting and fun to play [6].

MoCHA (Monitoring Cognitive Health using Apps) is a set of tablet-based games designed to provide convenient, low-stress, affordable monitoring of cognitive health for elders at risk of developing Alzheimer's disease. Through the research, it was found that it is possible to design psychometric games for older players while creating games that are genuinely engaging and fun [9].

B. Interview

Interview was done with a doctor in order to enhance the understanding of CVD as well as further information regarding the subject.

C. Survey

Survey questions was adapted from 2012 PopCap Games Mobile Gaming Research by Information Solutions Group (ISG) in 2012 [11]. The survey was conducted in order to decide which type of game would be best suited in order to make an enjoyable educational game. Respondents were from the targeted age group of the game that is 15 to 40.

III. RESULT

A. Interview

Through interview, it was found that there has not been any research institution for CVD in Indonesia. It was also found that the cure for CVD has been developed in the form of therapy, although it has not been fully proven and has not been available in Indonesia. Screening test was switched from Ishihara Test to Panel D-15 after the interview was done.

B. Survey

From the survey result, it can be concluded that most of the respondents prefer mobile game compare to PC and console game. Among the respondents, Android is also more popular and iOS or other operating systems for smartphone. Most of the respondents were claimed to be casual gamers with gaming time was less than 2 hours every day. Regarding genre of the game, roleplaying game were the one with highest number of respondents; but due to the effectiveness of information delivery authors decided to choose adventure which is also popular among the rest of respondents.

C. Game Design and Implementation

1) General Idea of "Color in Life" Design

"Color in Life" is a visual novel, adventure, educational game where the player will follow the story of Sherlock, the colorblind main character. In order to advance and finish the game, player will have to finish mini games that are implemented in the game, such as hidden object, puzzle, quiz, and color sorting games. Player will also engage in conversations, and he/she will be faced with options for replying the characters in the game, in which the options they choose can affect the level of difficulty in the mini games he/she will be playing. While finishing the game, player will be educated with knowledge about color blindness and color in general.

The design of the game is intentionally oriented to dichromatic colorblind people. All the mini games are designed accordingly so that those can be finished by the colorblind. Color sorting mini games are used as instruments to determine whether or not someone is colorblind, which is the gamification of Farnsworth- Munsell Dichotomous D-15 color blindness test. To prevent confusion that can be experienced by the colorblind from too many colors on the screen, grayscale colors are applied to the backgrounds.

2) Core Mechanics of the Game

- Conversation: Player will follow along the narration provided and will have to choose certain options to continue the narration at certain times. The options can affect the storyor the mini games (Fig. 1).
- Hidden Object: Player has to find the hidden objects listed before the designated time runsout (Fig. 2).

- Puzzle: Player has to drag puzzle pieces into the main puzzle (Fig. 3).
- Quiz: Player has to answer questions about color blindness correctly before the designated chances runs out. The questions will be based on the facts provided along thegame (Fig. 4).
- Color Sorting: Player has to sort colored blocks from left to right accordingly (Fig. 5).

3) UML

The game is consisted of three levels which preceded by level zero as introduction.

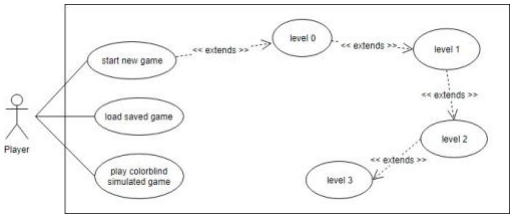

Fig 1. Main Menu

The players will be navigated to Main Menu when they first open the game. In this scene, players can either start a new game, load saved game, or see the credits.

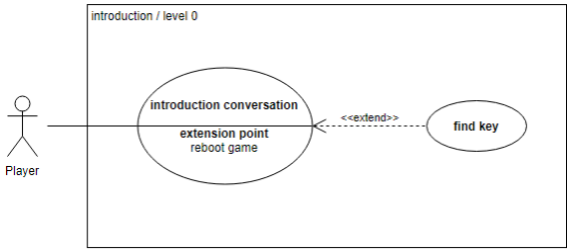

Fig 2. Level 0

The players will meet Sherlock, the main character on the game, which then he will explain how to play the game.

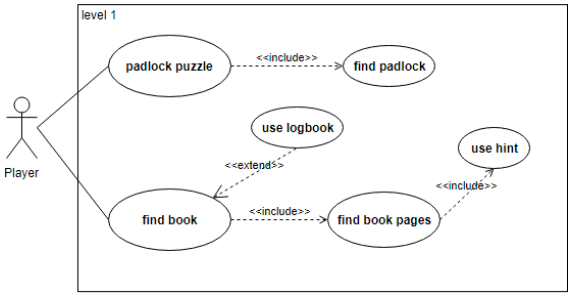

Fig 3. Level 1

In level 1, players will play puzzle and hidden object mini games, and player will unlock logbook function at certain point. The logbook can be used to check out the color blindness facts.

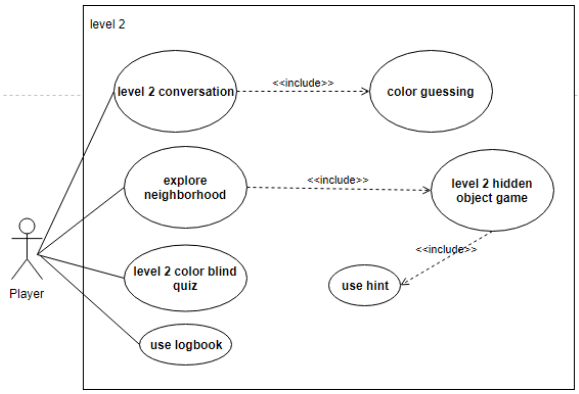

Fig 4. Level 2

In level 2, players will play all kinds of mini games, and players will unlock red color on the game if they answer the right option.

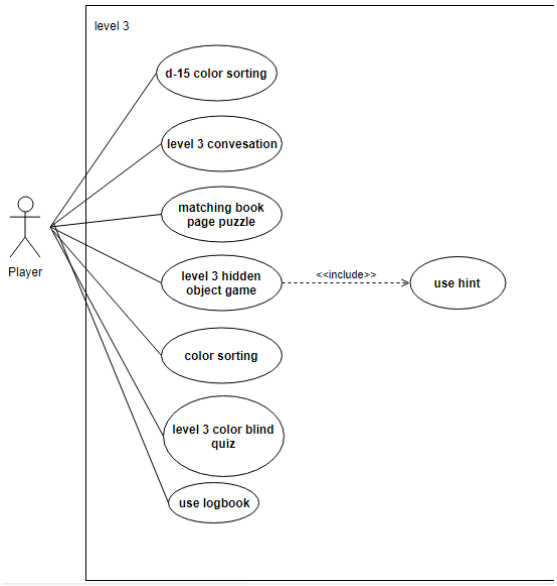

Fig 5. Level 3

In the last level or level 3, players will play all kind of mini games, and players will unlock green color on the game based on the color sorting result.

This game is implemented with Unity game engine version 2017.2.f3 and is targeted to mobile devices with Android operating system, 1 GB RAM memory, and 300 MB available space memory.

Fig 6. Conversation

Fig 2. Hidden object mini game

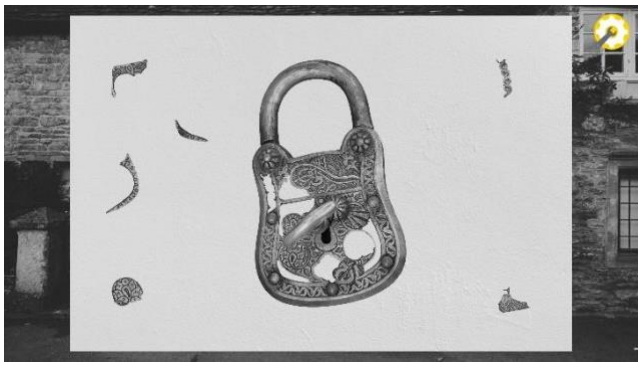

Fig 7. Puzzle mini game

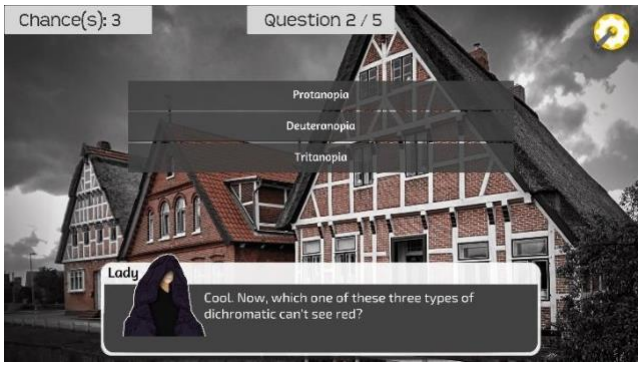

Fig 8. Quiz mini game

Fig 9. Color sorting mini game

D. Research Findings

The research was done in two methods, which are paired samples t-test and Core Elements of Gaming Experience. Statistical sampling technique was used to determine 35 players as the samples. These players are consisted of two groups, 32 players with normal eyes, and 3 players with color blindness. The numbers are based on the population of colorblind in Indonesia, which is 8% from the whole population.

1) Paired Sample T-Test

In the game, two same exact tests have been implemented, in which the players have to go through them before they start the game and after they finish the game. The test is consisted of 7 questions about color blindness. These tests were then used as the instruments of t-test [14] to calculate how much the game has helped the players in increasing their knowledge about color blindness by subtracting the total of correct numbers the players got from those twotests.

The result can be understood with the format t(degrees of freedom) = t-value, p = significance level. In this case, the result is $t(34) = -7.704$, $p < 0.05$. The average score from the first test is 3.03 ± 1.505 and the second test is 5.54 ± 1.120. It can be concluded that there is an increase in players' knowledge about color blindness because the value of t is a negative number that indicates the higher score calculated from the second test. The result can be categorized as significant based on the value of p which is lesser than0.005.

1) Core Elements of Gaming Experience(CEGE)

After finishing the game, players are requested to fill the CEGE Questionnaire (CEGEQ) which is consisted of 38 statements and can be rated with a 7-point Likert scale. This method is used to calculate how much the core elements throughout the game can be enjoyed by the players. The Cronbach's alpha for the whole questionnaire is 0.866 and can be considered reliable. Based on the statistics calculation that has been done, the game design is proven to be enjoyable by the two groups. The comparison can be seen through the average scores of 5 scales from the CEGEQ, which are Enjoyment, Frustration, CEGE, Environment, and Gameplay. For the group with normal eyes, the average scores are 0.763, 0.388,

0.710, 0.803, and 0.693 consecutively, and for the group with color blindness, the average scores are 0.651, 0.453, 0.686, 0.802, and 0.690 consecutively.

IV. Discussion

Though there is a significant increase concluded from the paired sample t-test, there is one player that answered less correct numbers on the second test, and several players answered same correctnumbers on both tests.

The average Enjoyment score can be seen significantly higher than the average Frustration score on both groups, while the score from non-defected group is higher than the defected group. The average Environment and Gameplay scores are similar from both groups, indicating that the graphics, audio, mechanic, and scenario are suitable for the game. The overall core elements value can be understood from the average CEGE scores, which are pretty good from both groups.

These results have proved the stated hypothesis that an educational game that is purposely designed to help dichromatic colorblind can help raise knowledge and awareness of the players regarding CVD and can be enjoyed by both defected and non- defected.

From this research, other game developers are encouraged to put core elements of the game, such as graphic and mechanic, into more consideration. Therefore, the game they are planning to deploy can be more entertaining to more group of players, specifically colorblind players.

Visual novel game has also been proved to be an effective genre of game in helping players expanding their knowledge and awareness on certain topics while still having fun throughout the game.

V. Conclusion

Color blindness should be taken more seriously by people, whether they are colorblind or not. It should also be one of the considerations for game developers when they are creating and designing their game. Having knowledge about color blindness and color in general can help colorblind people to cope with their daily activities easier. Therefore, authors have developed a dichromatic colorblind-oriented, educational game that not only can help players to expand their knowledge about color blindness, but also can be enjoyed by most players, whether or not they are colorblind.

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