Android Game for Amblyopia Treatment: A Prospective Study

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Abstract Amblyopia (also known as lazy eye) is a kind of poor vision that affects only one eye. It happens when the brain and the eye do not cooperate together properly. In such case, the brain cannot identify the sight from the impacted eye, and it becomes increasingly reliant on the stronger eye over time. Consequently, the vision of the weaker eye deteriorates. It is a complex symptomatic of sensory and motor functional disorder. Its main manifestation includes disorders of central and peripheral vision, light and color perception, contrast, electrical sensitivity and liability, and accommodative ability. According to statistics, around 2–3% of the entire world population suffers from amblyopia, which is equivalent to 10 million people under the age of eight. In Saudi Arabia, the prevalence of amblyopia in most of the clinical studies is 9.5%. There are a wide variety of treatment modalities, the most common is to wear a patch over the strongest eye for weeks or months, forcing the lazier eye to do more work. Current treatments such as wearing an eye patch or using atropine eye drops may not be acceptable. Implementation of such treatments is challenging for parents as their children do not feel comfortable wearing the patch. Therefore, in amblyopia treatment, there is a need to actively influence the nature of eye movements, consistent with the sensory system. This project provides a design of a visual Android game, which aims to help in the treatment of amblyopia or "lazy eye." It demands the transmission of information to both eyes in order to operate cooperatively. Short-term results show improvements in some patients who followed this treatment method consistently

Keywords Amblyopia · Android · Game · Treatment

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1 Introduction

In medical practice, smartphones are becoming a more common and fast evolving instrument. A plethora of applications are now available in the market to assist clinicians in performing various activities related to medical care (See [1] and references therein). Such applications become essential in our life due to COVID-19 [2]. Specifically, for ophthalmology-related care, activities such as measurement of visual acuity, glaucoma, and amblyopia can now be achieved using smartphone applications. Amblyopia has been a major problem to many patients [3, 4]. Indeed, around 2–3% of the entire world population is affected by it, which is equivalent to ten million children under the age of eight. Hence, introducing and addressing new ideas to lower its effect are considered very important. Despite the progress achieved in the treatment of amblyopia, the problem of improving visual acuity remains very relevant due to the high rate of amblyopia. Traditional methods of restoring visual functions in amblyopia mainly aim at stimulating the sensory component, which does not exclude an indirect effect on the motor component. Consequently, in the treatment of amblyopia, there is a need to actively influence the nature of eye movements, consistent with the sensory system. In [5], the effectiveness of playing computer game is assessed for children with amblyopia. The logMAR visual acuity (VA) has been evaluated before and after the treatments. Based on that, an improvement in the mean VA has been observed after seven weeks. However, this improvement was not statistically significant for which the sample size needs to be increased. In [6], different treatment protocols were compared to determine the adequate treatment time. These protocols result in almost similar improvement in the visual acuity. A mobile game called Space Vision has been developed in [7] for visual acuity test and home-based monitoring. According to this study, it is found that the behavioral and aesthetic customizations are crucial to enhance the resonance between the patient and the game..

In most clinical investigations in Saudi Arabia, the prevalence of amblyopia is 9.5%, whereas the prevalence in population studies is believed to be 1.6–3.6%. Furthermore, 68.5% of amblyopic children in the study are unilateral, whereas 31.5% are bilateral [8]. This is considered very critical and demands serious attention, for the purpose of ensuring the safety and well-being of children. However, if a child was not treated from early age, he or she will develop with one dominant eye, and the other one will be considered a lazy eye. Professionals treat lazy eyes with an eye patch, in order to cover the stronger eye, for the purpose of enforcing the lazy eye to function (Table 1). The treatment usually takes several months, in order to let a patient to recover from the sickness. Such form of treatment has been annoying for many children and has affected their self-esteem, as they look different among their friends with an eye patch. It is worth mentioning that the patching treatment will eventually fail if wearing of the patch is not continued [9]. This also limits a child's activities at school, having a negative impact on his or her well-being. As a result, orthoptists and ophthalmologists are always on the lookout for a more suitable solution to the problem, i.e., a viable treatment that is also well-accepted and hence truly

Table 1 Amblyopia treatments

Traditional treatment	Developed treatment
Eye patch, eye drops, clinic therapy's	Games, designed to treat lazy eye
Both of these treatments take larger period of time, consume a lot of money, and affect patient self-esteem	This treatment consumes less cost and time, develops motivational environment among patients, encourages patients to score more, does not affect patient self-esteem

effective [10]. One of the developed treatments is known as Wow Vision Therapy, in which professionals assist their patients to overcome their obstacle through intensive office-based vision therapy [4]. Another achievement has been made by Amblyotech Company, which has managed to develop games, designed to assist lazy eye patients, and these games have been approved by professional doctors [11]. In this study, we design and develop an Android game [12], using Android Studio IDE, for amblyopia treatment. Specifically, the game is developed to help the children who suffer from amblyopia without visiting the clinic for special treatment, or wearing the eye patch. Also, we have created a Web site to explain the goal of the game and the way of playing it [13]. Likewise, the Web site includes a frequently asked questions section, through which parents can contact us and receive our consultation and recommendations. In addition, the Web site is written in Arabic, in order to provide assistance to the numerous Arabic-speaking parents, who have a child with amblyopia, and to encourage the children to play the game [14]. We want to make the Web site in Arabic, in order to make it easier for them to understand the idea of the game. Furthermore, a patient can view their score in the game, and depending on the score, he or she can move to the next level. A patient is not able to increase his or her level on the first few days, since it requires both eyes to work together. Since the patients have one lazy eye, they can move to the next level after much practicing in the game. Hence, it is possible to make a weekly report to compare the results of each patient, in order to estimate the improvement in each of the age groups.

1.1 Playing Therapy

Playing therapy is a strategy of meeting and adapting to children's health needs, and it is widely recognized by specialists as a successful and appropriate intervention in dealing with the development of children's brain [15]. The developed form of this game and the Web site will allow involved people such as doctors, children's parent to connect with patients more quickly and dynamically, in which they can follow up on their health status. This game is designed for a smartphone, tablet, with Android OS, and the Web site allows doctors and parents to access information when and where they need it, such as the children score before and after playing, comparing their result with other children in the same age. This process can be helpful in which

the doctors will be up to date with the patient health status. On the other hand, the developer can improve his game according to the children statistical results and the doctor's instructions. The game provides familiar objects to the children such as shapes, squares and music. It also provides an easy instruction to the children about how to play such as arrows (left—right—up) and the score he gets on each level. This score is the key that doctors can determine the improvement process on the children medical status.

1.2 Study Objectives

The main objective of this game is to help in treatment the children with amblyopia. Besides, playing allows children to express their thoughts and feelings using their most comfortable method (playing). So, playing therapy will give children a chance to process their therapy in enjoyable way. Game will allow the doctor to adjust the required levels of exposure to each eye of a patient, leading the work of the left and right eyes to a synchronous position.

2 Literature Review

The development of effective methods for the treatment of this pathology is one of the most important tasks of pediatric ophthalmology. Amblyopia is the second most frequent (up to 6%) illness after myopia, which is the reason of the decrease of children's visual acuity in preschool and school age. In connection with the late appointment of an appropriate correction of refractive errors, the development of refractive amblyopia is observed in 33–98.4% of children. The prevalence of refractive amblyopia with hyperopia reaches 70%. By its nature, amblyopia is a functional pathology of the higher parts of the central nervous system, and its pathophysiological basis is persistent cortical inhibition of the function of central vision, which develops as the result of sensory deprivation in early childhood. In fact, the development of amblyopia is associated with the disruption of interneuron interactions at various levels of the visual system—from the sensory retina to the external cranial bodies and central regions in the occipital lobe of the cerebral cortex. Amblyopia is a complex symptomatic complex of sensory and motor functional disorders. Its main manifestation was previously considered a decrease in visual acuity. However, as the pathogenesis and clinical picture of this disease was studied, a number of other disorders of central and peripheral vision, light and color perception, contrast, electrical sensitivity and lability, along with accommodative ability, were detected. According to modern concepts, the main goal of treating refractive amblyopia is to achieve the maximum and consistently high visual acuity (0.4 and higher). The first simple and traditional methods of treating amblyopia are penalization and direct occlusion. The principle of these methods is to turn OFF the better Seeing Eye from

the act of vision. Penalization is most effective in 2–3-year-old children (97–98%) in the period, when there are no serious sensory impairments in the visual system. Yet, its effectiveness is significantly reduced (14.3–31.2%) at the older age. The disadvantages of this method are the duration of treatment (from 1 to 2.5 years) and the need for long-term mydriasis. Recently, various computer-based stimulation methods have been useful in the treatment of amblyopia. Computer programs increase the efficiency of the defective part of the visual analyzer due to a patient's sensible solving of visual problems. They contribute to the activation of brain neurons and the restoration of interneuron connections at all the levels of the visual system. This method has several advantages. Due to the capabilities of computer programs, there is a gradual complication of stimuli that are adequate for various channels and levels of the visual analyzer. The computer graphics arsenal provides tremendous opportunities for creating a variety of treatment programs, in which both automatic process control and accurate recording of the results of each session are provided. In all computer programs, medical procedures are provided in a game form with a patient's active participation, which greatly increases his or her interest and thereby shortens the treatment time. The ability to widely vary and dose the effects, along with changing the settings and the size of the stimulus, allows a researcher to individually select the treatment.

3 Methodology

The methodology of this project based on the game Dig Rush that Ubisoft was developed jointly with Amblyotech. The gameplay is designed to help in treating amblyopia or "lazy eye," a disease, where one eye cannot work synchronously with the other one and the brain. The doctor can adjust the required levels of exposure to each eye of a patient, leading the work of the left and right eyes to a synchronous position. Additionally, different load allows training the mobility and speed of the problem eye on nerve impulses. The game approach to correcting this problem is appropriate due to the ineffectiveness of the existing treatment methods. The classic approach is to increase the load on the affected eye, which usually requires putting a bandage on the healthy one. However, the main disadvantage of the method is that in order to achieve the desirable result, one has to do the dressing for several hours every day. The bandage imposes certain restrictions, as a child's development is slowed down, since he or she has to know the world and learn to evaluate the perspective and distance, which is difficult to do with one open eye. This will simply lead to the need to re-go through the cognition process later. In addition, the bandage creates discomfort and makes a child feel sick. Moreover, if one goes to school, most likely, he or she will not cover his or her eye. The game, in turn, stimulates a child to go through the whole process of treatment very quickly. In the process of developing the

game, the studies of ophthalmologists from McGill University have been considered. The game is designed for tablets and requires the use of 3D glasses. Moreover, it implements an adjustable level of contrast of red and blue, which are refracted by 3D glasses.

3.1 Study Design

The game involves wearing 3D glasses with red–green glasses and directing the red square to hit the blue one to collect score, so it depends on two colors (red and blue). In order to see different colors, the patients are required to wear 3D glasses. The information must be transmitted to both eyes enabling them to cooperatively work together. As a result of the increased plasticity in the brain, the amblyopic brain will be able to relearn. The game is now available on Google Play, and patients can download it on their phone, write comments, and view other parents' comments. The use-case diagram of the model is illustrated in Fig. 1. In order to record users' scores in the game, we contacted with players weekly for the purpose of comparing patients' scores. If the score is too low, comparing to the other patients of same age, the patient should stop playing the game because that means low or no response at all. Otherwise, when the received score is high, the patient can continue playing the game.

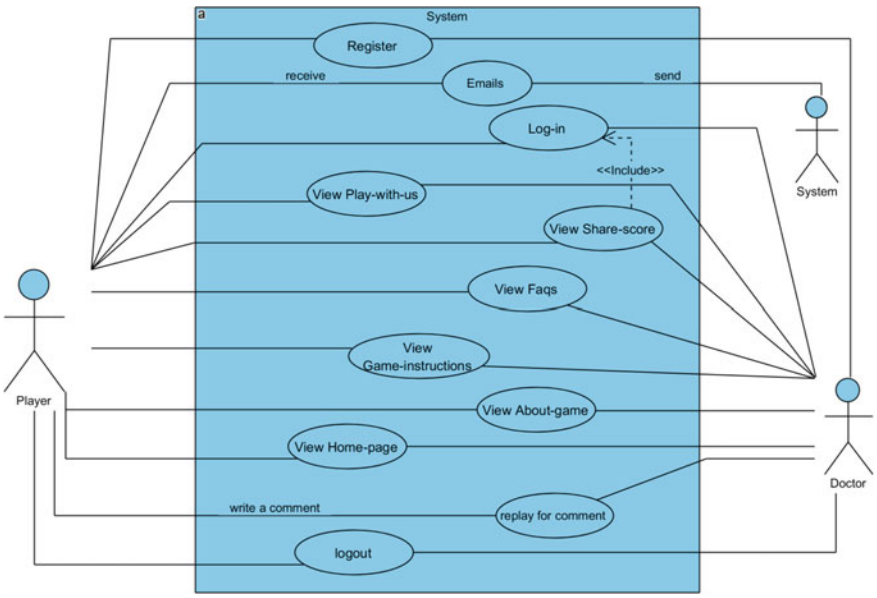

Fig. 1 Use case diagram

3.2 Sample Size

The sample was seven amblyopic patients from Dammam Medical Complex.

3.3 Data Collection

We visited the hospital and met patients and their parents, to explain the idea of the game and how they should play the game. Also, we gave the patients 3D glasses with red–green lenses to wear while they are playing the game. The patients were divided into groups depending on their age, and the measurements were recorded. We made sure that patients' identities remain secret. We met the patients weekly to get feedback. Then, and after one month, we met them again to do eye measurement tests and recorded the results.

3.4 Data Management

Patients played a game and received score for each completed level proceeding to the next level. The Web site collected scores and provided a report to compare the results of each patient every week, in order to estimate the improvement in each of the groups.

4 Results

In this section, the obtained results for amplyopia treatment using Dig Rush game (shown in Fig. 2) are presented. Seven children with amblyopia from Dammam Hospital have participated for testing the proposed treatment method. The average age of these participants is seven years old. They are divided into two groups. One group is supposed to use the glasses for one month, five days a week, and an hour a day. Meanwhile, the other group received a closed bandage for the "lazy eye." Among four children of the first group, the conditions of two participants have been improved. One of them did not achieve any improvement as he/she was not committing to use the glasses. However, the participants in the second group who wear eye patch on their "lazy eye" do not show any improvements. The child's parent gets benefit from the Web site which explains the idea of the glasses and benefit of the glasses over other treatments. Table 2 shows the children information before using the glasses and their results after the proposed treatment. It is evident from the obtained results the advantages of the proposed solution (game and Web site) for children with "lazy eye."

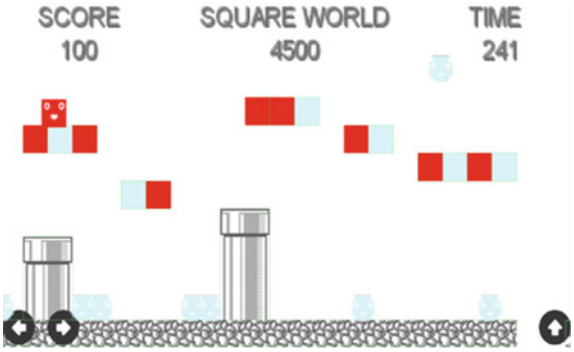

Fig. 2 Dig rush game used in amplyopia treatment

Table 2 Summarization of children treatment score

#	Child	Visual acuity	Visual acuity after using the glasses
1.	Patient 1	**Rt:** −7.50 −3.5 5 **Lt:** +3.00 −1.75 175	Improvement 0.3
2.	Patient 2	**Rt:** +8.50 −1.25 170 **Lt:** +8.00 −1.25 175	Improvement 0.4

Fig. 3 Mohammed, a 4-years-old amplyopic patient is using Dig Rush game as a treatment

With the binocular treatment, the average amblyopic eye visual acuity (VA) letter score is enhanced from baseline by 1.3 (2-sided 95% CI: 0.1–2.6; logMAR 0.026). However, with continued spectacle correction solely, it is enhanced by 1.7 (2-sided 95% CI: 0.4–3.0; logMAR 0.034). After the adjustment of baseline visual acuity (VA), the difference of letter score across groups (binocular minus control) is obtained as −0.3 (95% CI: −2.2–1.5, $P = 0.71$, difference logMAR: −0.006). According to the data acquired from the iPad, it is observed that more than half of the partici-

pants in the binocular group have completed more than 75% of the recommended treatment. These include 58% and 56% of the participants in four and eight weeks visits, respectively. It is worth mentioning that significant improvements have been observed especially for one case of the seven patients (shown in Fig. 3). Unfortunately, other participants withdraw as their parents were not convinced in this type of treatment.

5 Conclusion

In this study, we have introduced the idea of designing and developing an Android game, using Android Studio IDE. The methodology of the project is based on the game Dig Rush that Ubisoft has jointly developed with Amblyotech. The game involves wearing 3D glasses with red–green glasses and directing the red square to hit the blue one to collect score. The game depends on two colors, which are mainly red and blue. In order to see different colors, a patient is required to wear 3D glasses. The information must be transmitted to both eyes enabling them to cooperatively work together. This way of treatment shows significant improvement, and more studies and evaluation should be considered in order to improve its efficacy. This study distinguished from the previous trials in being the first one that replaces the plastic glasses with VR Box Reality 3D Glasses, which obligate the children to see by their both eyes together and prevent seeing below the lower glasses border, besides these developed glasses put away the need to held large devices preventing later complications on the neck. We hope to improve this game more by adding face recognition feature that ensures that the same patient continues the game.

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