A Low-cost Virtual Reality Game for Amblyopia Rehabilitation

Angelo Gargantini
Department of Engineering,
University of Bergamo
Viale Marconi 5 24044
Dalmine (BG), ITALY
angelo.gargantini@unibg.it

Fabio Terzi
Department of Engineering,
University of Bergamo
Viale Marconi 5 24044
Dalmine (BG), ITALY
f.terzi1@studenti.unibg.it

Matteo Zambelli
Department of Engineering,
University of Bergamo
Viale Marconi 5 24044
Dalmine (BG), ITALY
m.zambelli3@studenti.unibg.it

Silvia Bonfanti
Department of Engineering,
University of Bergamo
Viale Marconi 5 24044
Dalmine (BG), ITALY
silvia.bonfanti@unibg.it

ABSTRACT
The paper presents the design and development of a mobile application realizing a video game that aims at treating amblyopia by using a Google Cardboard. Google Cardboard is a low cost device able to reproduce virtual reality by means of a smartphone. The proposed video game engaged the patient in a car racing game and it displays the same image to the eyes, but with some differences that stimulate the lazy eye more than the normal eye.

Categories and Subject Descriptors
Applied computing [**Life and medical sciences**]: [Health informatics, Consumer health]

General Terms
Measurement, Human Factors

Keywords
Amblyopia, Cardboard, Rehabiliation, Android, Mobile games

1. INTRODUCTION
Amblyopia, otherwise known as 'lazy eye', is reduced visual acuity that results in poor or indistinct vision in one eye that is otherwise physically normal. It may exist even in the absence of any detectable organic disease. Amblyopia is generally associated with a squint or unequal lenses in the prescription spectacles. This low vision is not correctable (or only partially) by glasses or contact lenses. Amblyopia is caused by media opacity, strabismus, anisometropia, and significant refractive errors, such as high astigmatism, hyperopia, or myopia. This condition affects 2-3% of the population, which equates to conservatively around 10 million people under the age of 8 years worldwide [8]. If amblyopia is not diagnosed and treated in the first years of life, the lazy eye becomes weaker and the normal eye becomes dominant. The traditional way to treat amblyopia is carried out wearing a patch over the normal eye for several hours a day, through a treatment period of several months. This treatment has some drawbacks: it is unpopular, not well accepted by the young patients, and sometimes can disrupt the residual fusion between the eyes.

Our group has been involved in the use of computer technologies for the treatment of amblyopia for several years. The project 3D4Amb[1] exploits the stereoscopic 3D technology, that through glasses with LCD active shutters permits to show different images to the amblyopic eye and the normal eye. We developed some software both for amblyopia diagnosis [3] and treatment that uses this kind of 3D technology [6]. A form of treatment we have proposed, consists in watching video clips with 3D glasses that realize a virtual visual rebalancing [2]. In this work we plan to advance w.r.t. the existing treatments by using a much cheaper virtual reality device and to emphasize the activity to be performed by the patients. Indeed, while patching and vision rebalancing are classified as passive method, other treatments which require some activity on the part of the patients are classified as *active*. Active methods are intended to enhance treatment of amblyopia in a number of ways, including increased compliance and attention during the treatment periods (due to activities that are interesting for the patient) and the use of stimuli designed to activate and to encourage connectivity between certain cortical cell types. A good survey and assessment about active treatments and their efficiency can be found in [5].

The active treatment proposed by 3D4Amb consists in playing with interactive games or exercises, which will stream

[1] http://3d4amb.unibg.it/

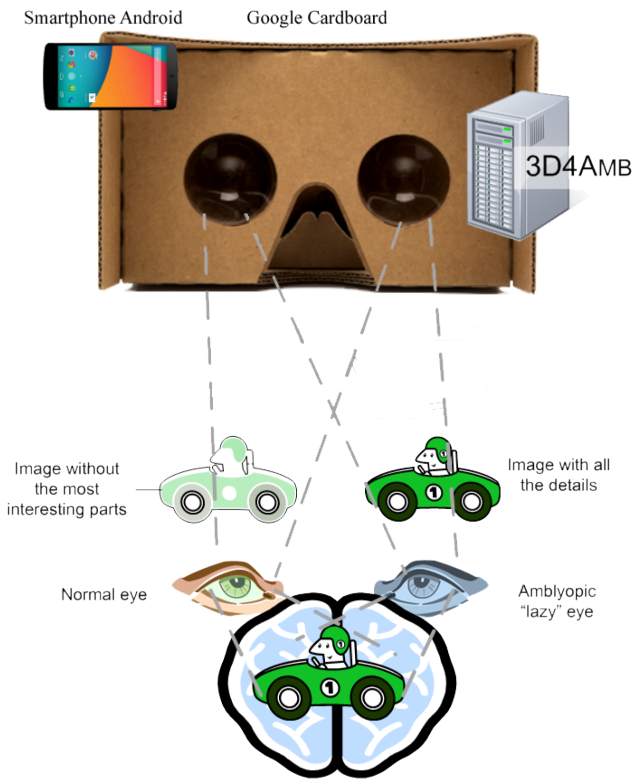

Figure 1: 3D4Amb system with Google Cardboard

binocular images. In this settings, the child plays with a special video game which will exploit the binocular vision to send to the lazy eye all the details while the normal eye will see only a part of the game scene. To successfully complete the game or the exercise the patient must use the information shown to the lazy eye (and possibly fuse it with the information shown to the normal eye). In this way, the amblyopic eye is more stimulated and the fusion encouraged. The game application must continuously monitor the success rate of the game in order to adjust the difficulty based on the real capability of the player. It is well known that video games can be very useful for visual rehabilitation [1]. Classical examples of games found in literature, include PAC-MAN and simple car racing games [7]. In this work we propose a simple car racing game.

The classic use of a 3D system (like 3D glasses or the Google Cardboard) is to provide different images to the two eyes of the same scene with viewing angles slightly out of phase, that correspond to the different points of view of left and right eye. This vision produces an illusion of depth of the scene and is the heart of virtual reality. The primary principle of the system is that the images shown to the two eyes are different but related.

This principle can be used in practice also for the treatment of amblyopia by sending two different images to the two eyes: to the amblyopic eye we will show the most interesting part of the frame of the clip (or game), while to the not amblyopic eye (or good) we will show the least interesting part. The principle, in case of use of the Google Cardboard is depicted in Fig. 1. Since the patients are young children, we decided to implement the diagnosis and treatment modules in a form of videogame, in order to make the treatment fun and not boring. The final aim of the project is to give the patients a complete system for the treatment that can be used at home. In fact, a smartphone and an inexpensive Google Cardboard are enough to run the software presented in this paper.

In this paper, first in Sect. 2, we describe the Google Cardboards and how they work. Then In Sect. 3, we introduce our mobile application that realizes the video game for amblyopia treatment.

2. GOOGLE CARDBOARD

Google Cardboard is a virtual reality (VR) platform developed by Google. It was created by David Coz and Damien Henry, Google engineers at the Google Cultural Institute in Paris, in their 20% “Innovation Time Off”[4], and introduced at the Google I/O 2014 developers conference for Android devices. It consists of a fold-out cardboard with two lenses where the user must insert the smartphone (see Fig. 2). The user looks inside in order to see the images displayed by the phone. It permits a stereo vision by sending two different images to the two eyes. It works with different smartphones and can be easily adapted to be used by children. The system proposed in this paper also works with other types of VR viewers (e.g., Samsung Gear VR).

Figure 2: Google Cardboard

It is not an experience as the strap-on Oculus Rift headset, which requires a computer (and is still in development), or SamsungâĂŹs Gear VR, which costs $200 and only works with the Galaxy Note 4. But it is an easy way to get a feel for what is possible with modern virtual reality, and beyond the low cost of the headset, most of the available apps are free.

3. CAR RACING MOBILE APPLICATION FOR AMBLYOPIA TREATMENT

The principle of using 3D for penalization of the normal eye in amblyopic children, as explained before, has been applied in the game development for the treatment of amblyopia. The game is called *Car Racing Cardboard (CRC)* which works for the Google Cardboard and it is freely available on the Google play store[2].

[2]https://play.google.com/store/apps/details?id=it.unibg.p3d4amb.carracingcarboard

Required hardware. The user must have an Android Smartphone (with the CRC application installed), Google Cardboard, or any other 3D VR glasses and earphone with controller (+, - and confirm) to play with the game.

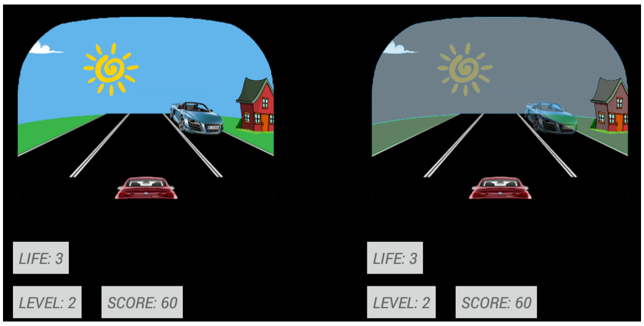

Figure 3: A simple game scene

Game principle. As shown in Fig. 3, the game scene shown to the patient is divided by CRC in two parts, one for the healthy eye (right eye in the figure) and one for the amblyopic eye (left eye in the figure). The CRC decides which images send to the eyes depending on the type of treatment suggested by the doctor. In any case the lazy eye of the child is stimulated to work and the healthy eye is not covered. This is a positive aspect since the children does not interrupt the merger between the eyes (it is a problem with the occlusion treatment, which can disrupt the residual fusion).

The brain of the patient has to combine the two images to view the complete frame successfully and perform simple operations like identifying the incoming cars and move the main car. There are a significant number of elements common to both images, to make sure that the patient can merge them. The final frame is a two-dimensional representation since the objective is not to stimulate the stereo vision of the patient (at least initially), but to make the eyes working in different way.

Game description. Before the beginning of game, the application allows the user to choose the lazy eye (left or right), in order to decide between two different views (penalize the right or left eye). The goal of the game consists in getting the highest score possible. The gamer moves the main car (in the bottom of the view) in order to avoid obstacles (i.e. incoming cars in the opposite direction), and if it does not hit any obstacle, then the score increases. When the score reaches some given thresholds (number of cars avoided), the level increases. When the level rises, the speed and the number of obstacles are increased as well so making the game more difficult. However, the most important aspect is given by the dynamic penalization of the scene shown to the healthy eye. In fact, when the level rises, the application increases the transparency of the panorama and the obstacles displayed for the not amblyopic eye, in order to train the lazy eye. The game ends after 3 collisions (after 3 lives lost). The gamer uses earphone to play the game. "+" and "-" buttons are used to choose the lazy eye at the beginning of the game and to move the main car in order to avoid obstacles. Instead confirm button is used to start the game or restart it after the end.

CRC improvement tracking service. The CRC game includes a web sever to which it sends data about the game activity. In this way, users can track their improvement. Once registration is complete (going on SIGN UP button (Fig. 4)), users can log in and the CRC system will trace game results. At the end of the game, users can ask to receive an email with a summary of the performance, in this way they can understand if they are getting better. Users can play also without registration, but the CRC system will not trace improvements.

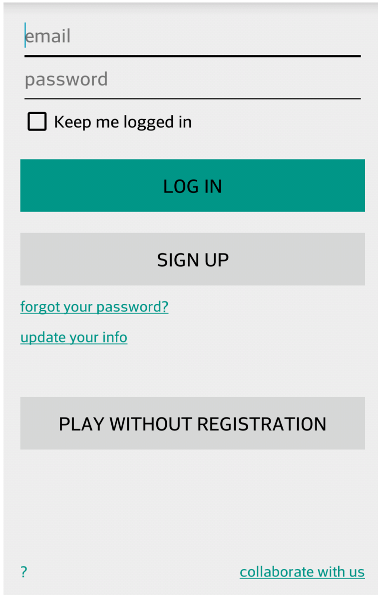

Figure 4: Log in activity

Doctor interface. CRC provide also an interface to the doctors to check patient improvements. Doctors can send an email to the CRC Staff, and they will provide to them a special page (Fig. 5). This functionality allows CRC to reach younger users, who are also the most affected by amblyopia.

Certifications. Until now CRC application has obtained the following certifications on Google Play Store (Fig. 6) :

- Australian Classification Board (ACB) – Australia
- ClassificaÃğÃčo Indicativa (ClassInd) – Brazil
- Entertainment Software Rating Board (ESRB) – North America
- Pan-European Game Information (PEGI) – Europe
- Unterhaltungssoftware Selbstkontrolle (USK) – Germany
- IARC Generic – Rest of the world
- Google Play –South Korea

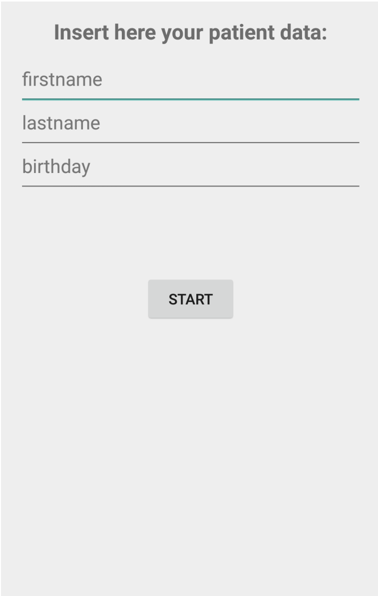

Figure 5: Doctor interface

Figure 6: CRC Google Play Store certifications

4. CONCLUSIONS AND FUTURE WORK

The application's aim is to treat amblyiopia or lazy eye, without requiring the use of an expansive device (nowadays all people have a smartphone and Google Cardboard is very cheap). By using the CRC application, people with lazy eye can improve their vision in the lazy eye. The policy for the treatment of amblyopia proposed by 3D4Amb, also tries to avoid the classical risks of the patch therapy (poor conformance and fusion disruption) and allows a interactive and supervised healing. However, at least initially, this therapy can be performed alongside with the classical occlusion. Although there are not clinical results available at the moment to support the effectiveness of the application, a series of experiments with children are currently carried on at the local hospital in order to check the validity and viability of the proposed approach.

Future development will be done in order to increase the motivation to play, e.g., a global classification, new cars when the user reaches an established score, a new landscape, and so on. A collaboration with some medical centers is going to start with the target to collect data from patients. It is also interesting to analyze how long the child needs to play before achieve some clinical improvement and how this method could replace or help current therapies.

5. REFERENCES

[1] R. Achtman, C. Green, and D. Bavelier. Video games as a tool to train visual skills. *Restorative Neurology and Neuroscience*, 26(4-5):435–446, 2008.

[2] A. Gargantini, M. Bana, and F. Fabiani. Using 3D for rebalancing the visual system of amblyopic children. In *Virtual Rehabilitation (ICVR), 2011 International Conference on*, pages 1 –7, Zurich, june 2011.

[3] A. Gargantini, G. Facoetti, and A. Vitali. A random dot stereoacuity test based on 3D technology. In *Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare - 2nd Patient Rehabilitation Research Techniques Workshop*, PervasiveHealth '14, pages 358–361, ICST, Brussels, Belgium, Belgium, May 2014. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering).

[4] N. Statt. Facebook has oculus, google has cardboard. `http://www.cnet.com/news/facebook-has-oculus-google-has-cardboard/`, 2015. Accessed: 2015-07-10.

[5] C. M. Suttle. Active treatments for amblyopia: a review of the methods and evidence base. *Clinical and Experimental Optometry*, 2010.

[6] A. Vitali, G. Facoetti, and A. Gargantini. An environment for contrast-based treatment of amblyopia using 3D technology. In *International Conference on Virtual Rehabilitation 2013 - August 26-29, 2013 in Philadelphia, PA, U.S.A.*, 2013.

[7] P. E. Waddingham, S. V. Cobb, R. M. Eastgate, and R. M. Gregson. Virtual reality for interactive binocular treatment of amblyopia. In *The Sixth International Conference on Disability, Virtual Reality and Associated Technologies*, 2006.

[8] A. L. Webber and J. Wood. Amblyopia: prevalence, natural history, functional effects and treatment. *Clinical and Experimental Optometry*, 88(6):365–375, Nov. 2005.