A Cross-platform Approach to the Treatment of Ambylopia

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***Abstract*—In this paper, we introduce a diagnosis and treatment for amblyopia performed through a game suitable for children aged between 3 and 7. Our method places emphasis on cooperation between the two eyes to achieve a good binocular outcome to aid the recovery of depth perception. Our approach is not limited to a particular device or platform nor even to a aprticular form of game. Several prototype games have been developed, including 2D games and 3D games.**

I. INTRODUCTION

It is estimated that 1 in 50 children will develop amblyopia [1], or lazy eye, as it is popularly known. In this condition, the child can see less clearly out of one eye and relies heavily on the "good" eye. Young children are often unaware that there is anything wrong with their vision, and even if they are, they are usually unable to explain what the problem is. Older children may complain that their vision is better in one eye than the other, and they may have problems with depth perception due to this mismatch.

Once diagnosed, one treatment that avoids surgery is to place a patch over the good eye to force the lazy eye to work. However, this patching, or occlusion treatment, can be unpleasant for the child and often delivers disappointing results for several reasons: it is unpopular, prolonged, and can sometimes make the overall problem worse because it disrupts whatever fusion there is [2].

If adequate stimulation is lacking during a critical or sensitive period of development in early childhood, certain cortical functions such as sight will never develop properly later [3]. We therefore target our approach on binocular vision with both eyes open, to provide more information for brain and help the overall development of the visual system.

Early intervention for amblyopia greatly increases the chance to reverse the condition and is the key to successful treatment. Thus, there is considerable current interest in designing effective and easily accessible approaches to the early detection and treatment of amblyopia

Our solution is to attract them into playing a game. With the ready availability of mobile Internet devices, most parents will be able to access these games online to assist in treating their children anytime, anywhere, thus reducing the burden on hospitals and clinics.

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II. RELATED WORKS

There is much on-going research in this field, and encouraging results have been produced within a short space of time.

A display system based on virtual reality (VR), called I-BiT™, uses a cyberscope to provide a virtual environment with a 3D view. The key feature of this system is to present static objects with less detail to the non-lazy eye and visually rich and dynamic objects to the lazy one. However, it has limitations as the hardware used makes treatment costly and it can be performed only in suitably equipped facilities under the supervision of a doctor (or at least, an adult). It is also not very accessible so treatment can be performed only for a limited time and only with precise scheduling.

Gargantini [2] describes a system based on binocular vision that is accessible, relatively low in cost, friendly to use, suitable for domestic use and easily extensible. It provides the two eyes with different images of the same scene with an offset in viewing angle that corresponds to the different viewpoints of the left and right eye, as in most VR systems. Their prototype is requires a standard personal computer with a suitable graphics card, a 3D-ready monitor with a refresh rate of 120Mhz and LCD shutter glasses.

Rastegarpour [4] thinks that VR-based treatment is costly and not accessible for most children so he introduced a method that could accommodate the advantages of VR-based treatment at a much reduced cost by using a pair of anaglyphic glasses.

To [5] describes a take-home game for treating amblyopia that is deployed on a mobile. An autostereoscopic lenticular layer covering the screen is used to separate the images for each eye and the method is convenient and of low cost. However, the lenticular screen has drawbacks – the range of angles within which the observer can see the entire image are limited, and the screen has to be aligned very carefully with the screen pixels for the separation to be realised effectively.

Healthy binocular vision produces important visual perceptual skills: binocular depth perception and stereopsis. The determination of how far away an object is comes partly from monocular cues, such as texture, focus and shading for depth perception [6], but experiments from [7] show that the depth perception is not a simple result of monocular local signs and that binocular capability is essential. For children with amblyopia, depth perception may be lost.

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III. Design Requirements

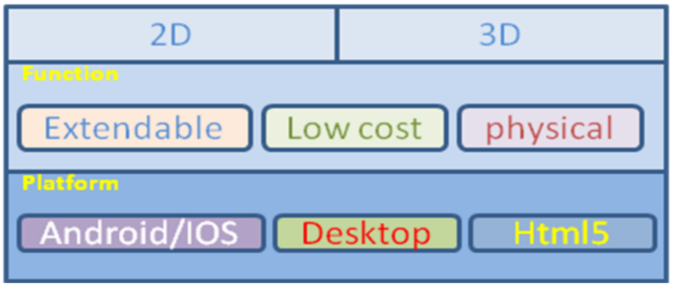


Fig. 1. Design Requirements

We targeted our work on multi-platforms to make it possible to perform the diagnosis or training easily almost anywhere. Since children often become bored, and therefore less cooperative, if expected to play the same game repetitively, we have made our method extendable to allow many different games to be included.

Mainstream stereo technologies include: parallex barrier, lenticular, shutter-based, polarised, holography and anaglyph 3D. Anaglyph 3D glasses were selected as they provide the cheapest and most accessible form of 3D display available to the general public. It is the oldest form of 3D technology but it is still widely used; its computational demands are low, thus widening the range of possible platforms for its deployment

IV. Game Design

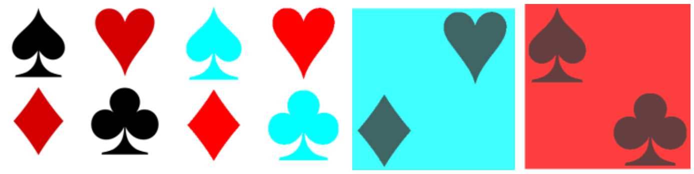
We designed several games that are suitable for lazy eye diagnosis and treatment; many other popular games can be converted for use in our training game. We expect that having a broad range of games will help to retain the children's interest and so encourage them to comply with treatment.

The patient has to wear a special pair of red-blue/cyan glasses to separate the view from right or left eye. These generally have cardboard frames so are light to wear and very cheap to acquire. The basic principle is to present an image separately to each eye, with the lazy eye being shown an interesting, dynamic and controllable part of the scene, while the good eye is shown less interesting parts (static items, the background, etc) so the attention of the brain is drawn to the content being viewed by the lazy eye..

We studied a variety of candidate game platforms and evaluated them from different perspectives: developing language support, 2D/3D support, functions, etc. We selected PlayN as our 2D game platform, and Unity as our 3D game playform; both meet our multi-platform requirement, supporting mobile phone, desktop and online games. We also used Jbox2D [8] for the 2D physics engine and the Unity3D [9] built-in PhysX physics engine to simulate physical systems, such as rigid body collision detection.

A. 2D game

Many card games are suitable for children, such as Old Maid, Go Fish, etc., and children often enjoy solo card games such as Patience. We take playing cards as an example to demonstrate to convert a normal 2D game into a amblyopia training game. A pack of cards contain 4 suits, hearts, diamonds, spades and clubs, in 2 colours – hearts and diamonds are in red while spades and clubs are in black (Fig.2a).



a b c d

Fig.2. Suit displays for different eyes

The most common type of 3D anaglyph glasses has cyan and red lenses. Cyan is the complementary colour to red; other complementary pairs include green/magenta and blue/yellow. The differently coloured lenses allow the eyes to capture two different images. In card games for example, we displayed the red heart and diamond in pure red (RGB - #FF0000) and the black spade and club in cyan (RGB - #00FFFF) (Fig.2b).

The eye with the cyan lens can see only diamonds and hearts and these are in black (Fig.2c) as the cyan filter blocks red, passing cyan. Meanwhile, the eye with red lens can only see spades and clubs in black (Fig.2d) as the red filter blocks the cyan. When playing the game, children need to be able to use the lazy eye cooperatively with the good eye. Of course, all four suits will now appear black to the person wearing the glasses, so recognition of the suits depends purely on the symbol, not on its normal colour, but in many card games, this is not a critical element.

There are many other 2D games can be transformed into training games in this way.

Fig.3 shows a Word Puzzle game we designed from scratch. Four groups of letters (see Fig.4) fall down from top to bottom for each column. Type 1 with background in cyan should be feed to the lazy eye with a red filter lens; Type 2 can be seen by both eyes; Type 3 can be seen clearly through the cyan lens. In addition, the anaglyph stereo image of a flower belongs to Type 4 – it is a universal letter and can be used to substitute for any letter to reduce the difficulty of the game. We give each type a fixed score, with the score being inverse to its order.

In the game, the player has to catch randomly appearing letters to finish a group of words shown one by one at the bottom on a red background. In this case, "apple" should be spelt letter by letter. Once it is done, next word in this group will be shown with the same style.

To catch these specified letters, there are 2 challenges for children. One is that the letters will disappear when they reach the bottom boundary of the game area with a new letter appearing at the top of that column. Another is the threat from the ball; this is a rigid body and may change direction and speed when it collides with edge of letters or boundaries of the game area. The ball makes letters disappear when it touches them. Children are given control of the ball through the keyboard by accelerating its speed in one of the four directions to avoid the letter disappearing.

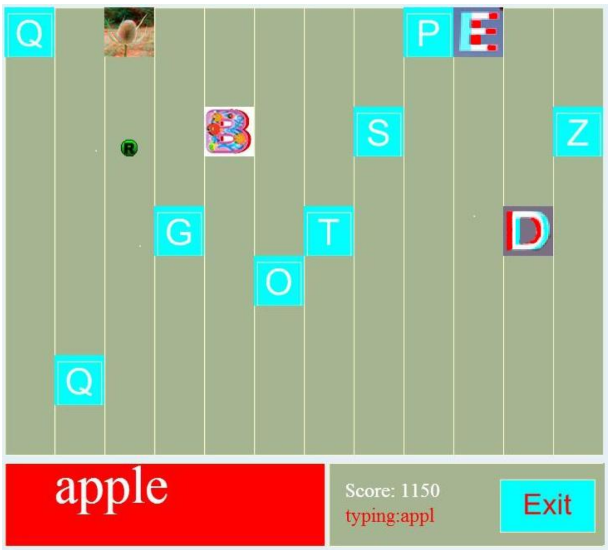


Fig.3. WordPuzzle game

Fig. 4. Four groups of letters

For this game, a pair of anaglyph glasses is needed, which is matched to the child's lazy eye. Normally, anaglyph glasses come with cyan on the right eye with red on the left, but some vary. The game allows the colour of the Type 1 letter to be set accordingly. If it is set to cyan, the background of word will be red, and vice versa.

The games have been deployed as Apps on Android Smart Phones and Tablets. With these touch-screen devices, a soft key board is not a good user interface, so the control activities were changed from a keyboard to a single-touch event through our control wheel. Another important configuration of our game for these devices is to adjust width and height of the game area. Some devices use a resolution of 1280×720, while others use 800×400. We use a fixed size for a letter block so that children can read it easily, but adjust the number of columns and rows of the game area by the *DefaultDisplay* parameters read from Android sdk API.

By analysis of the child's score over a period, one can measure if there is an improvement in his/her amblyopia. This game can be changed into other ways, for example, changing Type1 letters to simple animal shapes, Type 2 letters into anaglyph animal images, and the word into a group of animal shapes. This would make it more suitable for younger children.

Our 2D games was built on the PlayN[10] platform which meets our multi-platform requirement. It supports Desktop Java, which can be used on a desktop computer; HTML5 Browsers which enabled by the GWT (Google Web Toolkit) which allows developers to create and maintain complex JavaScript front-end applications in Java, and with the help of the Android SDK and API, our app can be deployed on a Android mobile or tablet device.

B. 3D game

Although binocular function can be measured by clinical tests through stereoscopic depth, a very young child cannot explain what is going wrong. From Wilcox [7], we can see that when the contrasts of the left and right images are equal, binocular vision can be progressively strengthened. Wilcox also reported that some people with strabismic amblyopia who are stereo blind to static disparities can detect dynamic disparities from motion-in-depth stimuli. The visual cue for position stereopsis (PS) is a difference in position between the retinal images of a visual object viewed by the two eyes (position disparity), while those for motion stereopsis (MS) are a difference in motion (motion disparity) and a change in the size of the retinal images.

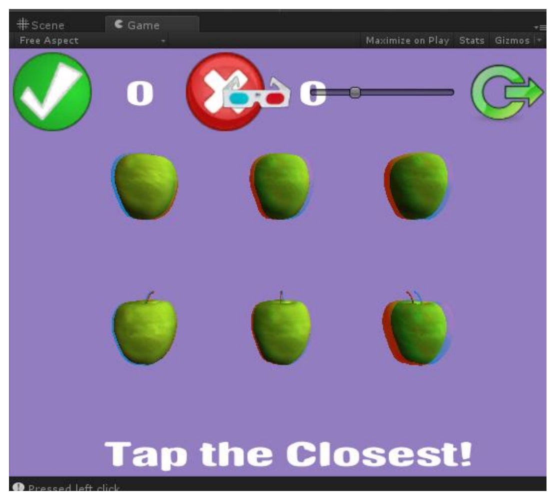


Fig.5. Static depth perception game AppleTap

In our 3D games (Figs.5and 6), dynamic stimuli are given directly from a 3D scene, so the user perceives the simulated world in 3D by the motion of rigid objects in the scene.

The basic platform we used is Unity3D, which supplies a cross platform mechanism that allow us to deploy our games on many devices, including smart phones. To Unity3D was added support from the Monodevelop IDE, which supports writing and debugging script languages such as C# and Js. Among the graphic functions supplied by the Unity3D Pro version, "Render-to-Texture Effects" is one of the most important. Render Texture is a special type of Texture that is created and updated at runtime. All rendering in Unity is done with *Shaders* - small scripts that let you configure the how the graphics hardware (GPU) is set up for rendering.

The AppleCatch game (Fig.6) aims to improve depth perception directly by viewing motion-in-depth stimuli, which is different from [4][5]. The apples falling from the trees and the bucket are 3D rigid objects with different depth values in the scene. The task of this game is to catch the apples by moving the bucket. When apples collide with the edge of bucket, they may change in depth, which provides a real experience of depth. Users have to decide the relative positions of the apples and the bucket in the scene. They are able to adjust the nominal distance between the eyes in the two views to make themselves comfortable.

Fig.6. AppleCatch game

With the help of Unity3D, the anaglyph effect (Fig.7.) is implemented through the following steps:

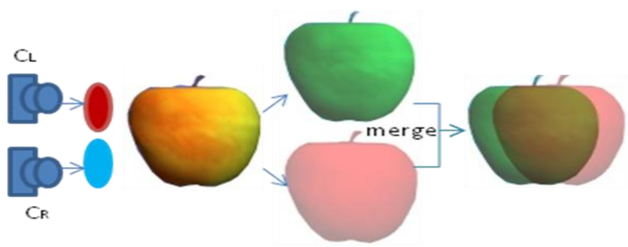


Fig.7. Anaglyph effect

1. Create two different cameras for the left eye, CL, and right eye, CR; a horizontal distance between these 2 cameras is used to simulate the distance between two eyes.
2. Create two render textures, LeftTex and RightTex, of the same size as the screen.
3. Assign these two Render Textures to the respective cameras.
4. Create a material which is given the matrices *Al* for the left eye and *Ar* for the right eye, where

$$Al = \begin{pmatrix} 0.3 & 0.6 & 0.1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \quad Ar = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0.3 & 0.6 & 0.1 \end{pmatrix}$$

5. In the shader, look up the Left texture vector VtexL and Right texture vectors VtexR of each pixel in the scene from 2D LeftTex and RightTex.
6. Compute the texture vector for each filter by:
   VfilterL = Al * VtexL
   VfilterR = Ar * VtexR
7. The anaglyph texture for each pixel can be computed as:
   Vanaglyph = VfilterL + VfilterR
8. An Occlusion Culling function is used for improving the performance at run time.

We also give this game a timer and a counter to record performance and the score that the user achieved, to encourage them to continue playing the game.

V. Conclusion

Our games are built in both 2D and 3D, based on the levels of amblyopia and the ages targeted. 2D games place more stress on the cooperation between eyes, which is a basic factor of depth perception.

Hess [11] suggests that adults with an amblyopic eye may still have their binocular function improved; we are aiming to make our work extensible, to attract adult patients to play more complicated games in the future.

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