Chapter 27
Syt-AJ: Treating Lazy Eye Using Virtual Reality

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1 Problem Definition

Amblyopia or commonly known as “Lazy Eye” is a vision development disorder wherein the vision of the normal eye overpowers the vision of the affected eye and the affected eye is unable to achieve a visual acuity of a normal eye [1]. This condition is normally observed in a single eye and in rare cases affects both the eyes. The disorder is caused due to poor coordination between the brain and the eye. Some of the physical factors involved in cause of amblyopia are poor eye alignment, irregular eye shape or irregularity in the visual acuity [2]. Because the brain does not develop the ability to see clearly in one or both eyes, the eyesight cannot be improved with glasses alone.

This disorder commonly occurs in children and younger adults. Early detection helps in boosting the success rate of treatment. The system we designed for treating amblyopia includes therapy as a series of exercises and activities that help a person improve their visual skills. Vision therapy helps restore a person’s binocular vision, which is the root cause of the condition.

Our system overcomes the shortcomings for the existing the solutions. Our approach defines deployment of a VR environment application which can be accessed by anyone and everyone throughout the world. This can eliminate the availability factor for the amblyopia treatment.

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Considering the cost factor for the technique, instead of available commercial VR sets and controllers switching them with available Google Cardboard and a Bluetooth controller for interacting with the VR environment, this significantly reduces the cost factor of the technique. This helps the individuals who cannot afford surgeries or costly VR software to receive proper treatment for amblyopia. But, the usage as discussed should be carried out under proper guidance or an ophthalmologist.

2 Literature Survey

Detection of amblyopia or rather symptoms of this disorder for those who suffer from mild form is not aware until they get tested, since the normal eye views the environment ordinarily.

There are a range of active and passive therapies in terms of the methods used to treat amblyopia. The diagnosis of amblyopia is done by identifying the eye with lower visual acuity and correcting it to the good eye. Treatment is continued as long as the player is able to perceive depth and see objects and the environment properly. It is not suggested to continuing to eye patch for more than 6 months if no improvement is recorded [3]. Deprivation amblyopia is treated by removing the opacity as soon as possible by eye surgery, followed by patching the good eye to boost the use of the amblyopic eye [4]. The earlier the amblyopic eye is detected and treatment is initiated, the easier and faster the treatment is and the less subjectively stressful. Also, the chance of achieving 20/20 vision is greater if treatment is initiated early [5].

The following is the list of available treatments for amblyopia [6]:

- Eye patches
- Eye surgery
- Vision therapy software
- Vivid vision gear
- Lazy eye shooter.

The above approaches are discussed below while considering their advantages and disadvantages.

2.1 Eye Patches

Based on the principle on which amblyopia occurs, occlusion therapy is a passive and effective method to treat amblyopia. With eye patches, the good eye is covered, so that maximum processing is done by the lazy eye as shown in Fig. 1 [7].

The X ganglion cells in the cupped area of retina center and the dual-eye drive cells in vision cortex of the brain are stimulated to growth [8]. The main objective of using patches is to compel the lazy eye to concentrate on the objective. Covering

Fig. 1 Eye patches of amblyopia

the eyes is a simple solution, but it is more effective than traditional methods. This method needs to be carried out in supervision of adults for children and can often cause uneasiness due to its anesthetic way.

2.2 Eye Surgery

Eye surgery is performed to strengthen the eye muscles which help in free movement in eye as shown in Fig. 2 [9]. This is usually performed in case of strabismic amblyopia [10]. Amblyopia is often commonly confused with strabismus. The idea of lazy eye generally makes people think of misaligned eyes or wandering eyes which is strabismus.

Strabismus is the most common cause of amblyopia. To avoid double vision caused by poorly aligned eyes, the brain ignores the visual input from the misaligned eye, leading to amblyopia in that eye (the "lazy eye"). This type of amblyopia is called strabismic amblyopia [1]. It can only be treated when the patient is a child.

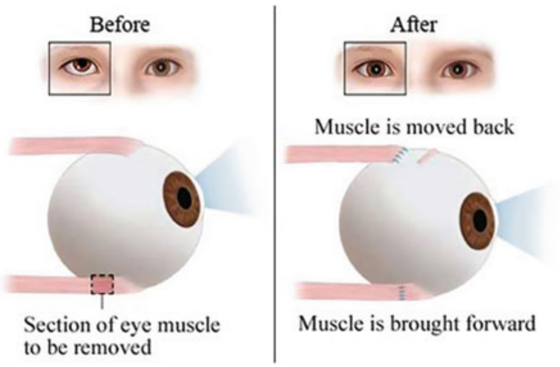

Fig. 2 Lazy eye surgery

The younger it is detected and treated the better. In fact, after age 6, the success rate of treatment goes way down [11].

2.3 Vision Therapy Software

Vision therapy software is a computer program that helps detect the symptoms of amblyopia. Amblyopia is a visual defect that glasses alone cannot fix. It involves a problem in the vision as well as the eye muscles which work out of sync with each other. The muscles of the eyes must work together toward proper focus and rest as and when required. The uncoordinated cause decreased visual acuity. Vision therapy software consists of a series of eye exercises done toward the computer, like a computer game as shown in Fig. 3 [12]. The initial tasks are simple. You need to find hidden 3D boxes across the screen using follow arrows on the screen which helps in increasing the visual acuity and in identification of movements of images. The computer dynamically increases the level of the game based on the player's improvement [13]. Each Vision therapy program is tailored to one's own personal binocular problem.

Fig. 3 Vision therapy software (VTS)

2.4 Lazy Eye Shooter

Experiments show that action video games have displayed improved vision as well as coordination in normal as well as amblyopic individuals. Playing action video games results in a range of improved spatial and temporal visual functions including visual acuity [14].

The lazy eye shooter has a dichoptic display-based architecture. The game involves a 3D stereographic display with faded image shown to the normal eye and the complete game environment shown to the amblyopic eye. Points and penalty in the game are partially based on focus with the amblyopic eye of the patient [14].

2.5 Vivid Vision Gear

Vivid vision treats lazy eye using a special mode called "diplopia mode" within which the game shows different image to the lazy eye compared to the normal eye, forcing the eyes to work in sync in order to get through to the next level as shown in Fig. 4. It uses a simple 3D brick breaker game in which the paddle is controlled by gestures on which the ball bounces and the player earns points based on the level of bricks [15].

In the game, paddle is visible only to the strong eye, the ball is visible only to the weak eye, and the bricks are focused on in the weak eye and dimmed in the strong eye. Using this technique, the game is able to break through the player's suppression. The game limits the amount of information visible to each eye and thus requires the

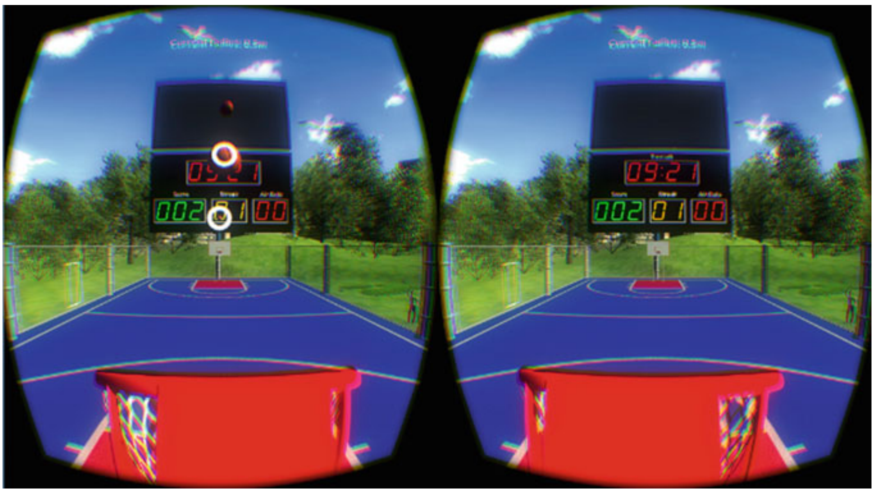

Fig. 4 Vivid vision hoopie

player to use both of them together and to make the brain understand the position of the objects in the game and merge the two sets of information available visually to develop a single frame or picture of the game environment. The fast-moving ball shown only to the weaker eye allows the patient to exercise the muscles of the weaker eye more than the normal eye which has the easier task of tracking the paddle and is not required to be more active. This allows the patient to perceive depth and 3D objects and as the treatment progresses allow the player to gain 3D vision in normal conditions [15].

3 Comparison of Existing Technologies

A comparison of the existing technologies is given in Table 1.

As the above table indicates, all the above technologies have their own merits based on different parameters. Eye surgery can be only performed on children below 16 years of age. The cost factor is also high, and time to recover on the other hand is definite. Complications can happen during surgeries, but the probability is very less. Eye patches again only work for children below 12 years of age. In most amblyopic cases, the age is a determining factor. Cost factor is very less, but the recovery time is again dependent on the severity of amblyopia. Use of patches can cause strain on the eyes of the children. Vision therapy systems do not have any age limit for usage, so as the other VR-based approaches for treatment. But, these commercial software lie on the higher end of cost factor. The recovery time is utility based. Usage of these

Table 1 Comparison of technologies

Treatment criteria	Eye surgery	Eye patch	VTS	Vivid vision gear	Lazy eye shooter
Usage	Children below age of 16	Children below age of 12	Everyone	Everyone	Everyone
Cost	High	$10 for 30 patches	$1000–$7000 with $152/visit to the doctor	$2000–$2500	Proprietary software of HTS (VTS).
Time taken in treatment	2–4 weeks for muscle movement	Usability based	Usability based (causing negative effects as well)	Usability based	Usability based
Side effects/complications	Complications in surgery	Strain in the eye	Headache, sore eyes	VR sickness, radiation due to continuous usage of system	Radiation due to continuous usage of system

devices is generally advised under expert guidance such as ophthalmologists. All these VR-based software a proprietary and are charged session based. Each doctor session costs around hundreds of dollars. This price range is not feasible for every individual. Also, the necessary gear required to use these software is costly. The overall affordability of these treatments for an individual is very high. This calls in a new technique for treatment which overcomes all the down factors for the exiting techniques.

4 System Architecture

Various components are included in our architecture (Fig. 5):

- User Input from Controller
  Takes the input from the user through Bluetooth controller.
- Input Control Mapping
  Maps the input to the player as well as the environment.
- Decision Making
  This module makes use of algorithms to take required actions in the gaming environment.
- Rendering the Changes in Environment
  The models are retrieved through the algorithm and are loaded in the environment.
- Display Output on the HMD
  The rendered changes are displayed in the HMD.

4.1 *Tools and Technologies*

- Blender 2.79 and Unity 2018.2 are used as a base to create our project.

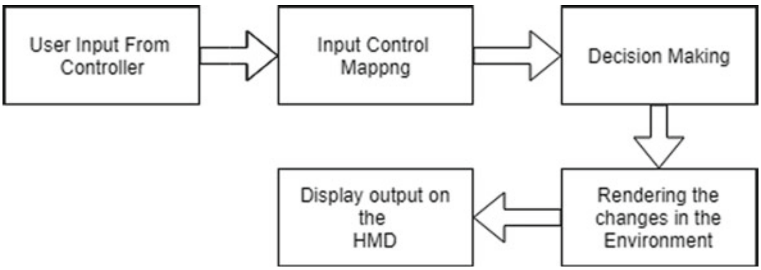

Fig. 5 System architecture

- Unity is a cross-platform game engine developed by Unity Technologies, which is primarily used to develop both three-dimensional and two-dimensional video games and simulations for computers, consoles and mobile devices.
- These open-source software are used for creating the game and uploading it on Google Play Store, so the application is available to all in need. Also, no internet connectivity is required while executing the project.
- Unity and Blender have a very strong and ever-increasing community of freelance developers, thus increasing the exposure and reducing the costs required to get assistance from developers.

5 Implementation

5.1 Referenced Scaling

Scaling the objects on the screen with respect to refractive index error in the eyes is also known as visual acuity. Visual acuity is dependent on optical and neural factors, i.e., (i) the sharpness of the retinal focus within the eye, (ii) the health and functioning of the retina and (iii) the sensitivity of the interpretative faculty of the brain, as shown in Fig. 6.

This specifies an individual's ability to percept depth in the virtual environment and increases the individual's stereovision.

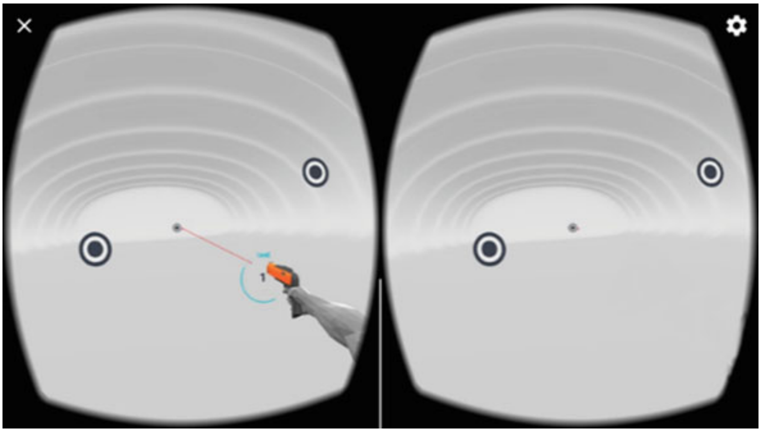

Fig. 6 Target shooter

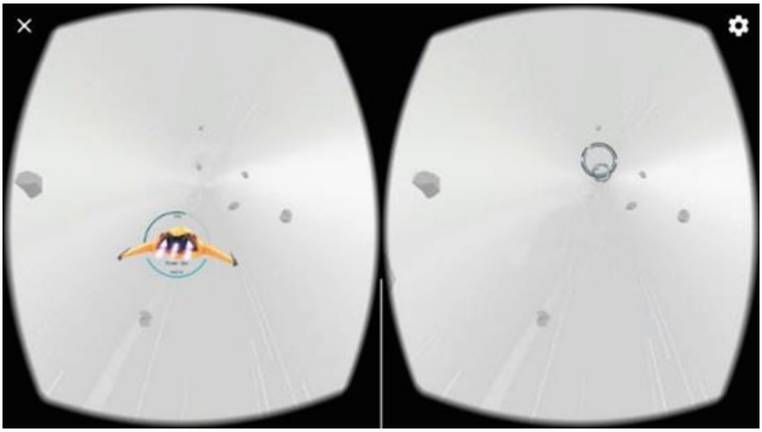

Fig. 7 Space shooter

5.2 *Differential Viewing for Each Eye on Screen*

It is the ability to adapt the contrast automatically which degrades the screen image which is visible to the player's good eye in a manner that is tailored for each player and the ability to display the game environment to the amblyopic eye for each player to interact with the game environment as shown in Figs. 7 and 8.

6 Testing

- The Syt-AJ system was tested on patients for 20 min (10 min each game), twice a week for 4 weeks.
- It was tested on patients of different age groups, having refractive amblyopia in left, right or both the eyes.
- The system was tested on two types of VR headsets—Google Cardboard and Aura VR (provided by system developers).
- The results obtained after testing are represented in Table 2: Testing result set.

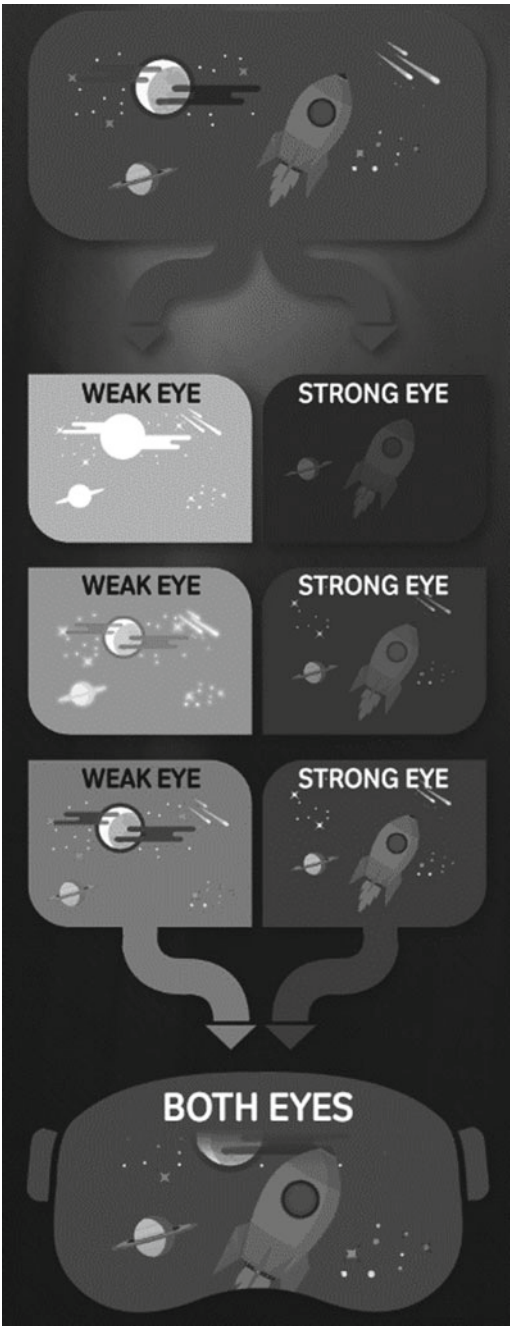

Fig. 8 Graphical representation of the system

Table 2 Training result set

Patient	Age	Amblyopic eye	Healthy eye RE	Dsph. Dcyl	Amblyopic eye RE	Dsph. Dcyl	BCVA—before training	BCVA—after training	Stereoacuity—before training	Stereoacuity—after training
1	7	Left	0.125	0.5	−0.5	0.5	0.5	0.3	Nil	140
2	12	Left	1.25	1	4	0.5	0.6	0.6 (personal lens)	140	220 (personal lens)
3	26	Left	−0.75	0	3.25	0	0.2	0.2	300	250
4	45	Right	1.75	0.5	2.75	0.75	0.2	0.2	260	260
5	9	Left	2.5	0	3.5	0.5	0.3	0.2	Nil	400
6	14	Right	−0.625	1	2.5	2	0.4	0.4	Nil	160
7	10	Right	0.25	0.5	1.75	3	1	0.7	40	200
8	18	Right	−2	0.5	−3.5	0	0.5	0.4	Nil	50
9	27	Right	0.5	1.5	2.25	1	0.1	0.1	Nil	20
10	23	Left	0.75	0	1.875	0	0.4	0.3	130	140
11	9	Left	0.5	1	1.5	0	0.6	0.5	Nil	400

RE—Refractive error
BCVA—Best corrected visual acuity

7 Conclusion

There is a direct need for a cost-effective system to deal with lazy eye for people belonging to all age groups. From the literature review, it is clear that the traditional systems are not cost-effective and efficient enough. Our system makes use of virtual reality to treat the lazy eye disorder replacing the existing systems in cost-effective and efficient manner. Also, the results after testing the system show important signs of progress in a patient's vision, indicating the success of the system.

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