



Chapitre d'actes

2012

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How to cite

BAYLISS, Jessica D. et al. Lazy Eye Shooter: a Novel Game Therapy for Visual Recovery in Adult Amblyopia. In: Games Innovation Conference (IGIC), 2012 IEEE International Games Innovation Conference. 4. Rochester, New York. [s.l.] : [s.n.], 2012.

This publication URL: <https://archive-ouverte.unige.ch/unige:92559>

Lazy Eye Shooter: a Novel Game Therapy for Visual Recovery in Adult Amblyopia

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Abstract— Training studies using action video games have shown enhanced post-training vision in both normally-sighted as well as amblyopic individuals. The purpose of this work has been the development of a game modification or “mod” using Unreal Tournament 2004 in order to combine conventional anti-suppression therapy principles for amblyopia with the benefits rendered by action video games for visual recovery and binocularity in amblyopia. The game system involves a stereo display with a degraded image shown to the “good” eye and game event items shown only to the amblyopic eye. Reward and punishment in the game is partially based on attendance with the amblyopic eye. Current results from a trial with 4 subjects show that all subjects recovered visual acuity and reported a dramatic reduction in switching between eyes with training, and were able to use their eyes simultaneously. A large sample clinical study is currently underway to further assess game efficacy.

Index Terms—amblyopia treatment, game, game design, lazy eye, UT2004, Unreal Tournament 2004, serious games.

I. INTRODUCTION

Amblyopia is a developmental abnormality that is a consequence of abnormal binocular visual experience during the “sensitive period” early in life. It occurs naturally in approximately 2-4% of the population and it can be reversed and eliminated when treated early. As many as three quarters of a million preschoolers are at risk for amblyopia in the United States, and roughly half of those may not be detected before school age [1]. Appropriate screening and accessible treatment are important.

Amblyopia can be reversed when treated early, but treatment is generally not undertaken for adults. A common method of treatment is to wear a patch over the “good” eye and there is evidence that performing near visual activities during

patching may be beneficial in treating children with amblyopia [2].

It is often stated that humans with amblyopia cannot be treated beyond a certain age [3]. There are, however, a number of case series that suggest that amblyopic adults can improve. For example Carl Kupfer showed marked improvement in acuity for 7 adult strabismic amblyopes, aged 18–22 [4]. All 7 showed improvements ranging from 71% (20/70 to 20/20 – PPR 0.29) to a very dramatic improvement from being able to report hand movements only, to an acuity of 20/25 after four weeks. Kupfer’s treatment was very aggressive as the patients were hospitalized for 4 weeks during which time they were continuously patched and given fixation training. Since Kupfer’s study, there have been a variety of reports for improvement in the acuity of older people with amblyopia [5, 6]. These reports have in common the fact that treatment, in general, went beyond simply correcting and patching of the amblyopic eye.

Recent studies with both normal subjects [10] and amblyopes [7] have shown that playing action video games result in a range of improved spatial and temporal visual functions including visual acuity. An exploratory study showed that prolonged periods of binocular stimulation can provide an effective treatment for childhood amblyopia and dichoptic display systems have been created for the treatment of amblyopia [8, 9].

The design of Lazy Eye Shooter takes advantage of these findings in that the software contains a dichoptic display for an action video game. This is not the only game for amblyopia treatment. Thompson, Blum, et. al. reported the release of an Apple iPod Touch game for treatment that used an overlay lenticular lens in combination with a modified game of Tetris [11]. In normal subjects, Tetris does not show the range of visual improvements promised by action video games [12] and

it remains to be seen if it can show such improvements for amblyopes.

II. LAZY EYE SHOOTER: A GAME FOR THE TREATMENT OF AMBLYOPIA

In designing the game, the first person shooter genre was chosen as it has demonstrated good results in previous research [12]. For the same reason and due to the project scope, the game was created as a “mod” or modification of Unreal Tournament 2004 (UT2004). Unreal Tournament is a first person shooter game that makes use of the Unreal Engine and the engine has extensive scripting capabilities for changes in game behavior in a language called UnrealScript. This built in functionality reduced development time significantly and promises to make maintenance of the game simpler for the future.

The new game type for UT2004 included the following features (shown in Figures 1 and 2):

- Display of two screens in the game window with the same game view for display to each eye either with a stereoscope or through the use of video eyewear
- A calibration image to move the screens in software in order to account for individual subject ocular deviation
- The ability to change the contrast dynamically in order to degrade whichever screen appears to the subject's good eye in a manner that is exclusive for each subject
- The ability to display an item (in our case a gabor patch) to the amblyopic eye within the game world
- The ability for the player to interact with the item that only the amblyopic eye can see
- A network connection and interaction with an outside program that controls the dynamic difficulty adjustment for the game based player performance as well as records and saves all necessary data for an experimental session
- Movement of all user interface functionality to the dichoptic display
- Training levels and a training paradigm for older subjects that have never played digital games before

- The ability for experimenters to change various parameters in the game from session to session as well as some of the parameters while the game is in play
- The ability to pause the game



Figure 1: A game calibration image. When the image is fused between two eyes the player sees a white cross surrounded by 4 squares.

The gameplay for Lazy Eye Shooter is a single player deathmatch game, where the goals of a player are to stay alive and shoot enemies controlled by the computer. Score is kept for a player's kill and death count in order to increase player motivation. In deathmatch, each individual is an enemy of every other individual (there is no team play). While the player is playing Lazy Eye Shooter, they are also provided with a secondary goal – to shoot or ignore a patch that appears in the game randomly and that is shown only to the amblyopic eye. The patch is shot if a gabor (Figure 3) is seen on the patch and it is to be ignored if the patch is blank. The spatial frequency of the patch is varied depending on how well a player does at shooting the patch at the right times. Figure 3 shows a variety of gabor patches at different grating frequencies. The higher frequency gabors are more difficult to see in the environment.

So that players pay attention to the gabor patches, a gabor patch rewards a correct player response with a percentage of health and ammo. An incorrect response spawns a new computer controlled enemy that immediately shoots at the player. This particular enemy is tougher than regular enemies to overcome.



Figure 2: Two game screens are shown. The good eye is shown the dimmed screen and the amblyopic eye is shown the screen with the extra object in it.

Originally, the gabor patch was spawned at a particular position in the world, but this led to players running up to the stationary gabor in order to see the patch better. The gabor patch now spawns at a set distance from the player and then continues to lead the player at this distance. Since the gabor exists within the game world and not just on the top of the game screen, this means that the patch can run into walls in the game. When this happens, the patch disappears and neither a monster nor reward is spawned.

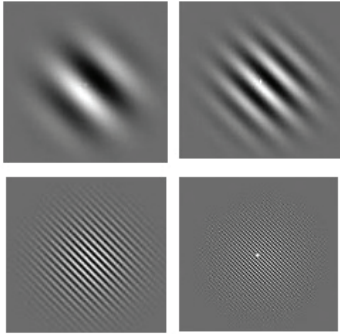


Figure 3: A variety of gabor images at different grating frequencies. The lower grating frequency gabors are much easier to see in the game.

If a player starts to take advantage of this system, the game first warns the player not to run patches into the walls with a message on the screen. It eventually starts to spawn enemies when the patch hits the wall if the player continues to exploit the system.

Since adult patients are not expected to be heavy game players, we have created a training paradigm for new players. New players may not be used to watching game action and so we found that removing patterns on the ceilings and walls of the early tutorial levels helped new players acclimate better to the game. Additionally, the training levels are built up from simple shapes and enemies spawn in only a couple of locations. This allows new players to practice the game mechanics in a safer environment.

III. PILOT TESTS

The dichoptic action video game was piloted on four adult subjects (S1-S4) with strabismic and/or anisometropic amblyopia. Informed consent was obtained from all subjects. The research protocol followed the tenets of the Declaration of Helsinki and was approved by the Research Subjects Review Board at the University of Rochester & UC Berkeley. Subjects were given a complete eye exam prior to participation. Subjects habitually wore distance refractive corrections with best-corrected visual acuities of 0.92-0.18 logMAR in their amblyopic eyes, and -0.24-0.04 logMAR in their non-amblyopic eyes.

Subjects were required to view split screen game windows through a stereoscope. To this end, subjects were presented with a nonius half-cross to each eye which, when viewed through a stereoscope and in the absence of suppression, would be perceived as a complete cross. The image contrast to the good eye was reduced so as to mitigate interocular

suppression. The stereoscope mirrors were adjusted to compensate for nonius cross misalignments arising due to ocular deviation. Subjects were trained for 1-2 hours/day, 3-5 times per week, for a total of 40 hours. An adaptive training regimen was followed in two phases. In phase one, subjects were introduced to simple training maps. The number of game bots and skill level were increased on a sliding scale tailored to each subject's performance (i.e. kill to death ratio). In phase two, subjects were required to play the original UT maps DM-Rankin and DM-Asbestos. The game difficulty was gradually increased at this stage by (a) increasing the image contrast to the good eye, and (b) increasing the skill level.

We used several outcome measures to assess training-induced changes. A range of clinical as well as psychophysical tests was used to assess various spatial visual functions before and after training. Here we discuss two standard clinical tests—ETDRS acuity test & Randot stereo-test. Figure 4 shows changes in logMAR acuity with training. Visual acuity (VA) recovered in all subjects. Post-treatment VA in the amblyopic eyes (Figure 4) was in the range 0.64-0.12 logMAR units, equivalent to 0.28-0.1 logMAR improvements. Stereopsis was nil before and after treatment owing to large angle strabismus in S1 & S2. S3 & S4 had measurable stereopsis (200 & 70 arc seconds) before training, and their stereopsis recovered to 25 & 20 arc seconds post-training. Although two subjects failed in Randot stereo-test post-training, all subjects reported a dramatic reduction in switching between eyes after training, and were able to use both eyes simultaneously. This is evidenced by an increased tolerance to a high contrast image in the fellow eye. Subjects S1 & S2 completed a 2-month follow up test battery post-training to assess retention effects. VA was found to be stable with no deterioration (see post-test 2, Figure 4). Our results demonstrate a real-world application of this novel game therapy in the rehabilitation of amblyopic patients. A large sample clinical study is currently underway to assess game efficacy.

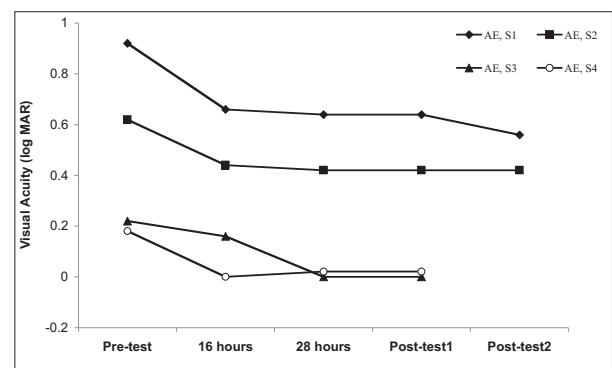


Figure 4: Changes in logMAR visual acuity before (pre), during (16 hours & 28 hours), immediately after (post-test 1) and 2 months after training (post-test 2). AE= Amblyopic Eye.

IV. FUTURE WORK

The game discussed is the first version of a treatment game for amblyopia and it is specifically designed to be comparable to previous work done with action video games. While the game works as it is, there are several features and design

considerations that need a deeper study and will provide future work.

First, the game has only been used with adult participants due to the violent nature of UT2004. Current work is focusing around designing a game that is more family friendly and that would receive a rating of E for everyone if it were to be rated by the Entertainment Software Rating Board. This means that there are no weapons that look like guns, there is no blood and gore, and there are no human death animations (including the player). We have chosen to make the game more cartoon-like and there is a minimal amount of cartoon type violence in the new version. This version of the game is aimed at children that are age 7 and older. This game is still under development and required a port of the original UT2004 gameplay to a newer version of the Unreal Engine called the Unreal Development Kit (UDK) in order to allow artists working on the project more freedom with level creation. Figure 5 shows a screenshot of this version of the game.



Figure 5: A more family friendly version of the game is under construction.

One of the main problems with the current game is that players must play the game for around 50 hours. While the game was designed to use all available levels that came with the original UT2004 game, they are still usually very bored of deathmatch long before 50 hours are reached. There are several ways of varying gameplay that could help with this issue. Right now, Lazy Eye Shooter uses only the original deathmatch type of gameplay. Modern first person shooters have iterated on this type of gameplay through giving players a wider variety of goals such as holding control points for a specific amount of time (in the game type Domination) and capturing an object to bring it back to a home base (in the game type Capture the Flag). We would like to include these game types in a future release of the game. Using different game types would give players different goals and help to stave off boredom, without requiring expensive additional content creation for the game.

Cooperative multiplayer should be considered, especially for parents whom have children with amblyopia and would like to participate in the treatment of their child. We do not believe competitive gameplay should be considered as many of the adult patients are new to games and competitive play could give them a bad taste for playing games if they lose to another person. The game is not currently design for multiplayer due to the extent of experimenter control needed in the game for experimental reasons.

We are not yet happy with the marriage between the game and the treatment system within the game. The gabor patch currently interrupts the flow of the game when it appears and it should be a more integral part of the game. The reasons for this particular implementation have to do with technical considerations for the scope of the project. For the future, we would be considering putting the gabor onto the uniform of a computer player and making the game so that enemies are those wearing the gabor uniform. The main technical issue with this is the constraint that the gabor uniform should only appear to the amblyopic eye. Since the game world is only a single place (two windows are drawn of the same world and then changed after the world is drawn), this could prove very difficult to accomplish. We are still working on other ways of increasing the involvement of the gabor patches with the gameplay for future versions of Lazy Eye Shooter.

ACKNOWLEDGMENTS

This work is supported by an Office of Naval Research grant (MURI Award 00140710937), National Eye Institute grants (NIH EY020976 and NIH EY016880), and the McDonnell Foundation.

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