Insights for More Usable VR for People with Amblyopia

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INTRODUCTION

Abstract

Amblyopia, or "lazy eye" is the world's most common neurological eye disorder. Yet, very little has been done looking into how to make virtual reality (VR) more usable for people with Amblyopia. Furthermore, a trend of using VR for Amblyopia therapy has arisen, making such a study more essential than ever. Our study asks our user base of people with Amblyopia questions through two surveys, verbal feedback, and interviews about their experience with our VR video game Amblyopia therapy. We found patterns encoded in this information, which we use to create preliminary hypotheses for making VR experiences as usable as possible for people with Amblyopia.

Background

Amblyopia impacts 1-5% of the population [19]. Amblyopia affects the connection between an eye and the brain, where the affected eye will have significantly reduced visual feedback. Due to this, the non Amblyopic eye becomes dominant and processes visual information more clearly and dynamically, causing the brain to atrophy the connection to the weaker eye. Symptoms include reduced visual acuity, reduced or lack of depth perception, blurry vision, susceptibility to the visual crowding phenomenon, and double vision in severe cases [19]. Such symptoms have been shown to lead to poor eye-hand coordination [20, 10]. It has been linked as a possible correlate of Dyslexia [9, 1] and it tends to lead to difficulty with reading [10, 14] and writing [7].

Recently, there has been an explosion in the use of VR for an alternative rehabilitation for Amblyopia [18, 13, 2, 3, 22, 8, 5, 21, 15]. Our comprehensive study on VR and Amblyopia, as well as others' studies, use the binocular characteristic of VR as an advantageous tool. Since VR isolates the eyes, it is easy to manipulate only one eye and not the other, which is *critical* for Amblyopia treatment. Most of these studies measure their success by testing vision changes exclusively [2, 3, 22, 21]. Other studies are so early in their development that they are still in the prototyping stage [18, 5]. In terms of usability, the closest thing we found was a paper discussing the usability of a rehabilitative game they created [4]. This paper mostly talks about usability in terms of the physical system, like using 2 screens as opposed to 1, and it measures success in terms of vision tests. However, they do mention two notable game design choices: users responded better to non-busy spaces, with non-textured floors and walls, and users did not have accurate mouse skills and kept trying to physically move the mouse [4]. We found a similar pattern in our own work, but we specifically hypothesize that it is due to known side effects of Amblyopia, and propose preliminary methods to overcome these issues. Overall, these studies are overwhelmingly focused on being assistive technologies and proving their effectiveness in correction. With the rise of VR games and the new interest of using VR for Amblyopia therapy, it is the best time to start a conversation on what makes VR games more usable (and therefore comply-able for therapy) for people with Amblyopia. With this study, we are hoping to start that conversation on what methods could be added to VR game designs to make them optimally usable. We explore the barriers experienced by our users and theorize how to best overcome those barriers.

METHODS

Our VR Amblyopia therapy entails our having our users play a VR video game we created. The game design is similar to fruit ninja, but instead, you catch gems with an ax. The game uses blur that reduces visual acuity on the dominant eye of a person with Amblyopia. Survey data was collected before using our VR game and after completing all VR sessions. Additionally, users were encouraged to "think out loud", as opposed to a "talk aloud", during each gameplay session. We also gave them an interview post-therapy. Our pre-therapy survey had 23 questions, focusing on users' history with their Amblyopia, compliance with previous Amblyopia therapies, and previous experience with VR. The post-study survey contained 15 questions. These questions were aimed at gaining an idea of the user's experience with our VR therapy, opinions on different aspects of the game, and compliance with our VR therapy. Our data is based on 9-10 participants. 10 users filled out the pre-study survey. Only 9 users filled out the post-study survey and attended the interview. 4 users were tested using different settings for visual crowding and kinematic requirements. All users had Amblyopia: 6 users with Amblyopic left eyes and 3 with Amblyopic right eyes. Of the 10 users, 6 were

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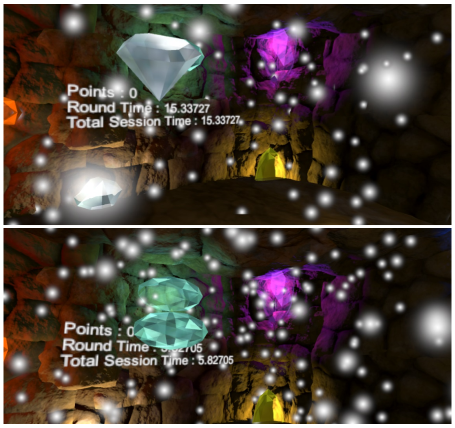

Figure 1. Shown: The 400 (top) and 800 particle system (bottom).

women, and 4 were men. Of the 9 users, 5 were women, and 4 were men. Seven of our users were age 21 to 23, two were 25 to 27, and one user was age 48. 5 users reported having used VR previous to our study. Our game design includes a factor of visual crowding, as most VR experiences and video games would. Visual crowding is the inability to recognize objects due to visual clutter or too many objects in their line of sight [23], something people with Amblyopia struggle with [6, 23]. Another factor we tested was the amount of movement required for the game. Movement is necessary for increasing neuroplasticity [12, 16, 17], and VR encourages this movement. However, movement can imply the need for competent depth perception and eye-hand coordination.

RESULTS AND ANALYSIS

The size of the spawning ranges determined how much the user was going to have to move to catch the same amount of gems. We found that 3 out of 4 users rated a 4.5ft range un-doable. Users reported that they felt that the targets that spawned on the outer corners were far away from them, and they had to more heavily rely upon their depth perception. We found that 4 out of 4 players felt 2.5ft or less was too easy. Making a range this small not only depleted the physical activity required for increasing neuroplasticity, but it was also not as fun. This created a loss of fun accessibility since a player with Amblyopia would not have as much fun as a person with healthy vision. We found the 3.5ft range on the x-axis (side to side movement) to be the most optimal for preserving play-ability and game integrity for people with Amblyopia. At this level, users did not have to rely as heavily on depth perception or keen visual acuity. It should be noted that requiring more movement does not mean a more effective therapy. Users reported that the more visual crowding we had in our game, the harder it was for them to perform accurately. This verified the pattern seen in users' average scores. Many users reported difficulty due to "over-stimulation" and not being able to distinguish important objects from unimportant ones. One way we found that overcame this was making our main targets (being gems) large, brightly colored and glowing to stand out among the white puff-like particles. Users reported that the neon-colored gems were easier for them to notice. The most accessible design for people with Amblyopia is to use minimal visual crowding. However, if jeopardizing the integrity or immersion of the game is the cost, it is important to find a healthy balance, so the game is not unplayable. We found an effective way to help users overcome the crowding phenomena was using targets or objectives that are easily distinguishable from the normal setting, as using aesthetically distinctive targets can trick the brain into giving them specific attention in the case of crowding for people with Amblyopia [11].

A frequent theme users reported while "thinking out loud" was that they liked that our game had an instructional scene with animated examples below the instruction shown. Another common theme from user commentary was that they liked that the informational scene was not timed at all. During the post-therapy interview, one user added on to this idea, saying that they had played games with tutorials where they could not keep up with the reading expectations. In one therapy session, our speaker was broken, and audio was not able to play while a user did the therapy. Though this case was taken out of the main study for not being consistent due to loss of audio, one interesting observation we had was that the user was more irritable and impatient than in their previous sessions. They scored below their typical average and were quieter during gameplay, implying that they were focusing more but achieving less. We credited this to the loss of audio confirmation when they touched a gem, which compensated for the loss of depth perception. Lastly, we found positive preliminary results that suggest our therapy can improve vision in the Amblyopic eye, even with our settings adjusted to be more usable to the participants, showing usability does not have to be sacrificed for efficacy or vice versa for VR Amblyopia therapy. Additionally, it should be pointed out that in terms of Amblyopia therapy, if one tries to sacrifice usability, the therapy will likely never be complied with.

CONCLUSION

Based on our user study, we make the following design recommendations in further work investigating the usability of VR for people with Amblyopia. We suggest visual crowding with no more than 50 distinct non-background objects identifiable in one frame, comparable or less than that shown in the top of Figure 1. We suggest that targets or objectives be large (at least the size of a small dinner plate) and aesthetically distinct (ideally, bright and colorful). Additionally, we encourage having audio associated with touch, as it offers confirmation of a collision and assists with poor depth perception. An even better addition would be using some recognizable beam coming out of the controller with a sphere that sits on the surface of an object to further confirm the distance of an object, as exemplified in a Microsoft paper on a Unity plugin for those with low vision [24]. Finally, having few to no time constraints in the context of reading expectations. As VR becomes increasingly popular for entertainment and Amblyopia therapies, these observations can steer conscious designers, especially those aiming to use VR for Amblyopia therapy, to design more intelligently.

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