Simulating the visual impairment symptoms of age-related macular degeneration in virtual reality

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A new virtual reality application visually simulates age-related macular degeneration and demonstrates its progression over time including some Charles Bonnet syndrome hallucinations.

Introduction

Age-related macular degeneration (AMD) is the leading cause of blindness in developed countries with the prevalence of this condition only expected to increase as the size of the older population grows [1]. The prevalence of late-stage AMD in the UK was found to be above 4% in those aged 65 and over, increasing to over 12% in those aged over 80 [2]. Even with the rates of diagnosed AMD already being very high, it has been found that the condition often goes under-diagnosed, especially in the older population [3].

Loss of vision due to AMD can negatively affect mental health [4], making daily activities more difficult and often leading to a lower level of physical activity and a poorer quality of life [5]. It can also be quite isolating, with many who suffer reporting that it prevents them from independently reaching local amenities [6]. AMD can also lead to poorer physical health, such as increased risk of falling, which is already higher for the older population [7].

Charles Bonnet syndrome (CBS) manifests in the form of visual hallucinations that occur as a result of vision loss alone, with there being no underlying cognitive impairment. Those affected are often aware that what they are seeing is not real and the hallucinations are rarely frightening or distressing. The hallucinations are well defined (not being affected by any concurrent visual impairment) and can take many forms, from faces and people to buildings and patterns. CBS often goes undiagnosed due to a lack of awareness of physicians and the reluctance of some patients to report their hallucinations for fear of being diagnosed as mentally ill. CBS is most common in the older population, in which AMD being the root cause of visual impairment is typical [8].

Figure 1: AMD simulation showing both visual acuity loss and central scotoma in virtual world.

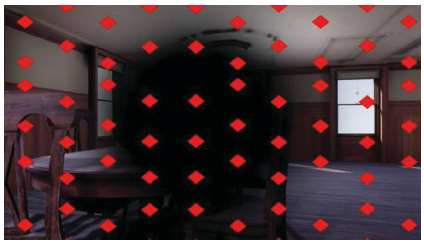

Figure 2: CBS simulation showing geometric diamond pattern.

Simulations of visual impairments in virtual reality (VR) have been created for a range of purposes – cataracts, glaucoma, AMD, and colour blindness have been simulated in contexts aiming to help architects and interior designers better understand the perspective of those living with these conditions [9]. Another common purpose is to help family, friends, and carers visualise the perspective of those with the visual impairments, thereby increasing empathy. This has been achieved by creating simulations of migraines [10] and simulations of visual impairments such as cataracts, glaucoma, and AMD [11]. Other simulations with this purpose have aimed to increase empathy towards the older population by simulating both visual impairments (such as AMD) and hearing loss [12]. While these simulations are often implemented in virtual environments, some work has been done on applying visual impairments (including AMD, diabetic retinopathy, and glaucoma) to a real-time video feed (where the camera is attached to the front of the headset) [13] and static 360° images [14].

Aims

The primary aim of this project was to create a VR simulation of how the world looks to someone who suffers from AMD, with the parameters of the simulation being customisable by the user. A secondary aim was to simulate several common types of CBS hallucinations.

Method

The simulation was created using Unreal Engine 5 [15], a popular video game engine with all the required capabilities. The headset used was the low-cost, widely available Oculus Rift S [16].

The visual impairment is viewed in a simple virtual world that is intended to be comfortable, familiar, and realistic, without being too distracting. In the AMD simulation, filters are applied directly to the user's view. These filters are made through a combination of high-level shader language (HLSL) and the visual scripting system built into Unreal Engine 5. The filters are designed to allow for the extent and strength of visual acuity loss, as well as the extent and intensity of the loss of contrast sensitivity (which at the maximum intensity would be a complete central scotoma) to be fully configurable by the user.

Results

An example of the visual impairment simulation can be seen in Figure 1 above.

Several types of CBS hallucinations have been implemented – distorted, disembodied faces that are incorporated directly into the user's view in a similar way to the AMD visual impairments, and geometric patterns of diamonds that slowly move around the user's visual field and slowly change colour (Figure 2). Models of children were also made to appear to the user using this method. The child models

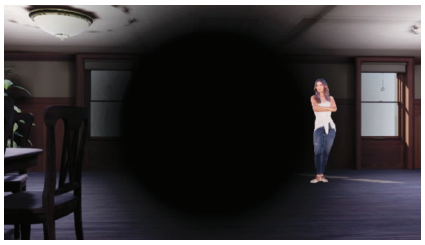

Figure 3: CBS simulation showing a hallucination of a person standing in the room.

Figure 4: CBS simulation of size-constant child hallucination.

do not move; they remain fixed in place relative to the user's field of view. Several models are built in and randomly selected each time the simulation is run.

Other CBS simulations are more complex, such as a person shown standing in the room with the user. This person remains in a fixed position relative to the room around the user (Figure 3) while being animated and showing internal movement such as crossing and uncrossing their arms.

The next type of CBS simulation demonstrates the effect of size-constancy. This occurs when the hallucination appears at the same depth as the surface behind it. This is demonstrated through a model of a child being placed into the virtual world in front of the user and always remaining in a fixed place in the user's field of view. The model is then moved closer to, or further away from, the user depending on the distance from the viewer to the surface being looked at. The model is then scaled to always appear to be the same size in the user's field of view.

Conclusions

This project has been successful in creating a working, customisable simulation combining AMD and CBS. The simulation allows for the user to independently control the central visual acuity loss and central vision loss in both size and intensity. The simulation also demonstrated numerous different types of hallucinations commonly experienced by those with CBS including a range of characteristics of these hallucinations.

The simulation environment shown here is ready to be transferred to a higher capability VR system, such as the Varjo XR3, that will facilitate eye tracking (so the visual impairments follow the user's gaze as it scans the scene) and allow the user to see the visual impairments and hallucinations imposed upon the real world around them, allowing for a more immersive experience of the visual impairments in a familiar and real context. Future work in this project will add more hallucinations and hallucination types to the simulation of CBS as well as more age-related visual impairments, such as cataracts or glaucoma, to turn this into a more comprehensive vision simulation. Further research would also include working with patients, or those close to them, to allow for input from those affected in evaluating the simulation's effectiveness and accuracy.

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1. A new, fully customisable virtual reality simulation of age-related macular degeneration.
2. It includes a guided timelapse showing the progression of the condition.
3. It includes some Charles Bonnet syndrome hallucinations showing size constancy plus internal and external movement.

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