IDeA: A Demonstration of a Mixed Reality System to Support Living with Central Field Loss

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Figure 1: On the left, a man is wearing augmented reality glasses while looking at a small clock, which is augmented with a simplified and enlarged clock-face. This supports users with visual impairment in overcoming challenges in everyday life. On the right, a woman wears a head-mounted display for virtual reality.

ABSTRACT

People with visual impairment face multiple challenges in their everyday life. They must regularly visit doctors to examine the progress of their impairment and advisory offices or local support groups to learn strategies to overcome challenges in everyday life. However, traveling to appropriate facilities itself often poses challenges to the patients. We propose IDeA, a system based on augmented and virtual reality technology for people with visual impairments. IDeA can lower the cost and improve access to medical care, support digitalization in treating visual impairments, and provide support in the everyday lives of people with visual impairments. IDeA is a three-fold system supporting: 1) the simulation of symptoms of visual impairments to raise awareness in persons without visual impairment, 2) showcasing early detection of symptoms and providing visual augmentations of the real world to support patients in overcoming challenges, and 3) supporting doctors through telemedical consultation, medical eye examinations, and the training of visual strategies. We outline the benefit for all stakeholders and how IDeA can improve the lives of people with visual impairment.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in accessibility**; **Accessibility design and evaluation methods**; **Accessibility technologies**.

KEYWORDS

Central Field Loss, Eye Tracking, Mixed Reality, Assistive Systems, Accessibility

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1 INTRODUCTION

According to the World Health Organization, over 195 million persons worldwide have a visual impairment, i.e., their visual acuity cannot be fully restored using prescription glasses or contact lenses [13]. The needs of individuals with visual impairments differ greatly. Even with the same diagnosis and visual acuity, the subjective perception will not be similar [5]. Therefore, diagnosing and helping people with visual impairment depends on highly individual examination and guidance. For such medical care, patients currently have to visit various different specific locations, i.e., hospitals or doctors' offices with special equipment and centralized advisory offices. However, one of the biggest challenges for people with visual impairment is traveling and navigation [10]. IDeA showcases a Virtual Reality (VR) environment for patients, doctors, and relatives of patients. It further demonstrates the capabilities of Augmented Reality (AR) glasses to assist people with visual impairments in their everyday life.

AR glasses can solve two different problems. First, for users without visual impairment, who use such AR glasses in their everyday life, the integrated eye-tracking could provide insights into the state of the eye and detect early stages of slowly progressing eye diseases [11]. Early detection will result in early treatment, thus, slowing down vision loss or even increasing visual acuity. Second, it provides the opportunity for displaying individual visual feedback tailored to the residual vision of a person with visual impairment [4]. This can be used to support people with visual impairment to overcome various challenges in their everyday life, like stairs [14], touchscreens [3], or shopping [15].

While current VR technology does have some limitations regarding the precision of the eye-tracking and the available field of view [7, 9], it can be used for measurements of the central visual field [7], measuring the deviation between the eyes in patients with Strabismus [6], or training visual strategies to increase the effective visual acuity of a person [8].

With this demonstration, we specifically look at age-related macular degeneration (AMD)—the leading cause of blindness in developed countries [1]. AMD leads to a progressing loss of the central visual field resulting in reduced visual acuity. The incidence of AMD increases with age [2], and given that the average lifespan of humans is ever increasing, the number of people affected by this progressive disease is rising as well [12]. To raise awareness of this impairment in relatives or friends of people with AMD, IDeA explains AMD and provides a simplified simulation of the symptoms—central field loss. To demonstrate a possible early detection system, we show a warning to visit a doctor during such a simulation. We also simulated AR using VR to display assistive visualizations in different situations, which the simulation proved to be challenging before. Additionally, the user can conduct two eye examinations—Amsler grid and perimetry. The system synchronizes with the patients' digital files for discussion and possible diagnosis with a doctor, who can access all information and choose what to show the patient in VR. Subsequently, the user can train peripheral fixation in a gamified training session playing the widely known game Pong.

IDeA can help people with AMD and those around them to take care of their daily tasks more easily and assist them in everyday life. Patients and doctors can benefit from easy and accessible eye examinations and telemedical presence.

2 THE IDeA DEMONSTRATOR

The VR system IDeA consists of multiple parts that demonstrate the previously mentioned use cases. A sketch of the different parts and their connection can be found in Figure 2. We show the benefit and function of each part in four different use cases, following Martha, a 60-year-old woman.

Early Diagnosis. Martha is an early adopter of modern technology and uses AR glasses daily. She wears prescription glasses but has not noticed a decreased vision lately. However, the AR glasses notify Martha about irregularities in her eye movements, which were detected using the integrated eye-tracking (see Figure 3a). Martha now visits a doctor and is diagnosed with early-stage age-related macular degeneration. Since she started treatment before she would have typically noticed the central field loss, symptoms are minimal and progress is slowed down early.

The Couch as a Doctor's Office. A few years in the future, Martha's central field loss grew larger. She regularly sees a doctor for treatment and examinations to monitor the progress of her disease. Additionally, she visits a local support group to keep informed about assistive technology and learn visual strategies to utilize her remaining vision better. However, these trips have become challenging and a burden for Martha. Her doctor prescribes her a virtual reality headset. Here, Martha can visit a virtual doctor's office, see Figure 3f, and consult with the doctor via voice chat and webcam. Martha can now start eye examinations like an Amsler grid test where she has to modify a grid until she perceives it as straight lines Figure 3d, with or without a doctor's supervision. The results are transferred to a digital patient file and can be accessed by the doctor via a web front-end or viewed by Martha in VR, see Figure 3g. Now, Martha can grant access to her medical data to an advisor of the local support group who can use this data to customize a gamified training session for Martha using a version of the game Pong, see Figure 3h. Using her VR headset from her couch Martha now regularly monitors her eye condition and conducts training sessions. An evaluation of these training sessions shows positive effects [8].

The Unaware Child. As Martha's central field loss is progressively growing and she needs more assistance, her son Ben is unaware of the challenges she faces daily. He cannot understand why she can walk around easily but requires help reading or why she did not recognize him when he walked past her on the street. Martha hands Ben her VR headset and starts the simulation. Ben is placed in the entry scene, see Figure 3c. Here, we display 3D models of the eye's anatomy, which Ben can zoom and rotate while detailed explanations about the cause and symptoms of AMD are given. Additionally, interviews with persons with visual impairments can be played on a big screen in the scene to highlight the challenges they face in everyday life.

In the next scene, Ben finds himself in a virtual living room. A simulated scotoma—a black spot in the visual field—is displayed and follows Ben's eye movements to block the central part of his vision, see Figure 3b. Ben has to perceive information using his peripheral field of view, which has a lower visual acuity compared to the center. Ben is asked to read the time from a clock mounted on the wall, switch on the TV, change it to a specific channel, and determine the

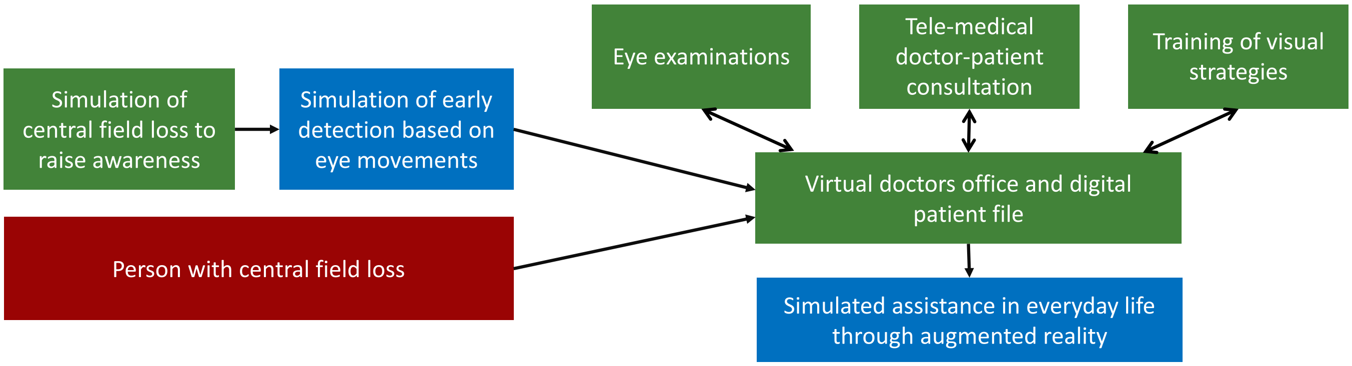
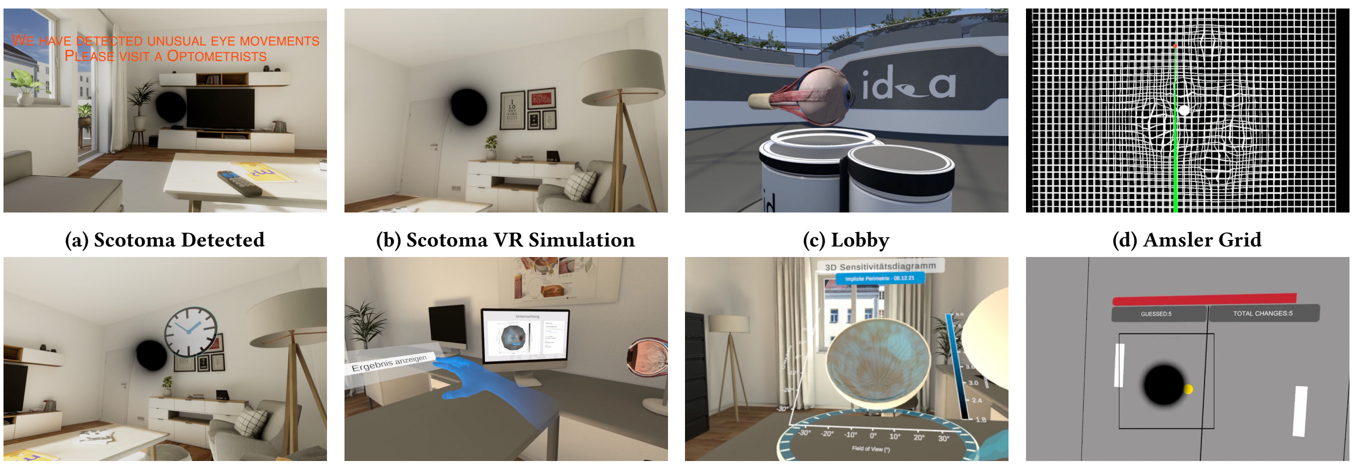


Figure 2: Here, we see a sketch of the different parts of the IDeA demonstrator. The whole demonstrator is implemented using Unity 3D and a Vive Pro Eye. The green parts are functional prototypes, which the user can experience. The two blue parts are being developed for augmented reality glasses and are only showcased in the demonstrator. The arrows represent the flow of the application and the possible flow of information between individual scenes.



(a) Scotoma Detected **(b) Scotoma VR Simulation** **(c) Lobby** **(d) Amsler Grid**

(e) AR Support **(f) Virtual Doctor** **(g) 3D Sensitivity Diagram** **(h) Training**

Figure 3: Here, we show the eight different scenes implemented in the demonstrator.

facial expression of the news reporter. Ben experiences firsthand that such tasks are challenging with AMD and understands the challenges people with AMD face regularly and can better support his mother.

The Everyday Assistance. Martha still uses her AR glasses regularly, which monitor her central field loss and notify her about changes. Further, Martha has customized her AR glasses to support her in navigating, recognizing faces, reading, and other everyday tasks by reshaping the visual information so Martha can perceive it. In IDeA, we simulate such AR assistance in the living room scene from Section 2 by augmenting the clock with a larger and visually simplified clock-face and the face of the news reporter with a simplified emoticon. These augmentations are visually simple, customized to the user. An evaluation in AR [3, 4] shows that augmentations can be perceived in the user's peripheral view, assisting them in their daily challenges and leading to a more self-independent life.

3 CONCLUSION

With IDeA, we demonstrate multiple facets that can increase the accessibility of medical care for people with visual impairment. We allow remote medical examinations, support the training of visual strategies, and enable discussions with their doctor in an unsupervised or remotely supervised fashion, all while reducing the need to travel. We showcase the use of AR glasses as an early detection device for the onset of visual impairments and as an assistive device after a diagnosed visual impairment. Lastly, our demonstrator already serves as a tool to explain and demonstrate the effects of AMD and raise awareness among friends and family of patients.

In the future, such systems can improve the everyday life of people with visual impairment and support independent living. Our demonstrator raises awareness in the research community about people with visual impairments and gives insights into current or future technological possibilities.

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