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A Virtual Mobility Test to Evaluate Functional Vision of Visual Impaired Patients

Presentation of the rationale, the test and first results in 42 normally sighted subjects

AUDREY CROZET, CHU Nantes, Ophthalmology department, Nantes Université, Ecole Centrale de Nantes, CNRS, LS2N, UMR 6004, France

LUCAS COMMUNIER, Nantes Université, École Centrale Nantes, CNRS, LS2N, UMR 6004, France

TOINON VIGIER, Nantes Université, École Centrale Nantes, CNRS, LS2N, UMR 6004, France

PIERRE LEBRANCHU, CHU Nantes, Ophthalmology department, Nantes Université, Ecole Centrale de Nantes, CNRS, LS2N, UMR 6004, France

PATRICK LE CALLET, Nantes Université, École Centrale Nantes, CNRS, LS2N, UMR 6004, France

The use of virtual reality (VR) in ophthalmology is still underdeveloped, although it is more and more used, whether in the field of diagnosis, therapy or rehabilitation. Currently, there is a lack of methods for assessing and measuring functional vision in visually impaired patients. Indeed, although much progress is being made in the development of innovative treatments for blinding diseases such as gene therapy or retinal prostheses, many clinical research studies are not completed due to the lack of functional vision assessment criteria adapted to visually impaired patients. The aim of our research is to develop and validate a new method of functional vision assessment for visually impaired patients. We hypothesized that virtual reality would be an interesting and useful tool in this context. We developed this tool, and evaluated it on normal sighting subjects. We plan to evaluate it in a future prospective study comparing healthy subjects and visually impaired patients with central, peripheral or mixed impairments.

CCS Concepts: • **Human-centered computing** → *Laboratory experiments*; • **Applied computing** → **Life and medical sciences**.

Additional Key Words and Phrases: Visual impairment, Virtual Reality, Ophthalmogenetic

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1 INTRODUCTION

Visual impairment is a public health problem, affecting 2% of the population. However, its global assessment is difficult to apprehend because of the multiplicity of pathologies, their variable impact

Authors' addresses: Audrey Crozet, audrey.crozet@chu-nantes.fr, CHU Nantes, Ophthalmology department, Nantes Université, Ecole Centrale de Nantes, CNRS, LS2N, UMR 6004, Nantes, France; Lucas Communier, lucas.communier@gmail.com, Nantes Université, École Centrale Nantes, CNRS, LS2N, UMR 6004, Nantes, France; Toinon Vigier, toinon.vigier@univ-nantes.fr, Nantes Université, École Centrale Nantes, CNRS, LS2N, UMR 6004, Nantes, France; Pierre Lebranchu, pierre.lebranchu@chu-nantes.fr, CHU Nantes, Ophthalmology department, Nantes Université, Ecole Centrale de Nantes, CNRS, LS2N, UMR 6004, Nantes, France; Patrick Le Callet, patrick.lecallet@univ-nantes.fr, Nantes Université, École Centrale Nantes, CNRS, LS2N, UMR 6004, Nantes, France.

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on the different visual functions, the possible compensatory mechanisms and the numerous methods of measurement. Beyond the precise quantification of visual function deficits, it is necessary to assess their translation into functional tasks related to vision and more generally their impact on patients' quality of life. To allow a more global measurement of functional vision in the case of disability, a mobility test (Multi Luminance Mobility Test) has recently been proposed to evaluate the patient's movements under standard conditions on obstacle courses [5]. Recent, rare and expensive, it has played a key role in assessing the medical benefit of the first gene therapy in ophthalmology (Luxturna) [2, 3, 5]. A virtual reality (VR) device would have great advantages by multiplying the measurement parameters while facilitating its dissemination: longitudinal monitoring of the disease, adapted medical and social response, suitable for use in an office environment, fine evaluation of the clinical efficacy of new gene therapies and artificial vision devices (prostheses), which are currently very promising. However, to the best of our knowledge, there is currently no validated device for assessing the functional vision of visually impaired patients using virtual reality. The aim of our research project is to develop a virtual reality mobility test, adapted to visually impaired patients, as a tool for assessing functional vision. This project is part of an active collaboration between the Laboratoire des Sciences du Numérique de Nantes and the Ophthalmology Department of the CHU of Nantes [7, 8] on the use of immersive media and eye tracking to study the influence of peripheral and foveal scotoma on visual attention.

2 RELATED WORKS

2.1 Evaluation of functional vision in ophthalmology

Beyond the precise quantification of visual function deficits, it is necessary to assess their impact on functional tasks related to vision and, more generally, their impact on the patient's quality of life. This assessment is most commonly made using subjective questionnaires [14, 15]. These standardized questionnaires are a valuable resource for accessing the experiences and feelings of people with visual impairment. However, they do not provide for a detailed and objective description of functional visual impairment in ecological and daily tasks, and the scores from these questionnaires do not always correlate with the scores from visual function tests [4, 16, 17]. Controlled laboratory tests that provide a simulation of real-life scenes that stimulate functional vision are highly relevant assessment tools. They are known as mobility tests. One such test, the Multi Luminance Mobility Test (MLMT), was developed to evaluate the efficacy of an innovative gene therapy, voretigene neparvovec (Luxturna), a treatment for a blinding disease called retinitis pigmentosa with a specific genetic mutation [5]. This test consists of a course with obstacles that the subject has to negotiate at different luminance levels. While no effect of the gene therapy could be measured using traditional visual tests, the improvement in the time taken to move to lower luminance levels after treatment allowed this innovative treatment to be reimbursed. However, the use of this test requires a dedicated large room with calibrated luminance, video recording and trained teams, which is very expensive and time consuming. In France, only three university hospital centers have this tool, because of the cost, it is reserved for functional vision assessment within specific research protocols.

2.2 Evaluation of functional vision in virtual reality

A recent systematic review of the literature on the use of VR and augmented reality in ophthalmology identified only 23 articles in the "Visual Assessment" category [12], of which less than 10 works concern the use of VR to assess functional vision. The use of VR in navigation or object detection tasks has shown significant differences in performance between healthy subjects and those with mild or severe visual impairments (glaucoma, central or peripheral visual field loss) [1, 6, 10, 11, 13].

Recently, the MLMT test has been adapted in VR [1] showing interesting preliminary results in patients with retinal dystrophy. In their device, Aleman et al. chose a physical movement of the subject walking with the head-mounted display (HMD) in a special room. In this VR mobility test, subjects follow arrows through the course, avoiding collisions with objects and must find a door at the end. Obstacles included stepover objects, cubes and spheres at given heights, and a (moving) pendulum. The layout of the paths varied from a test to another to limit the learning effect, but each test had the same number of obstacles ($n=17$) and turns. In a pilot study, they evaluated their VR mobility test on 3 patients with Leber congenital amaurosis (two of them before and after gene therapy), and on 7 normally sighted controls. They show that virtual reality was an interesting tool for assessing functional vision in visually impaired subjects with inherited retinal dystrophies. However, although the choice of the use of real navigation in VR appears to be more ecological, it can lead to sensory-motor conflicts for obstacle collisions, can raise safety issues for people with severe visual impairment and limits its use in clinical practice because of the floor space required. Furthermore, the advantage of virtual reality lies in the automated collection of attentional and behavioral data. In physical and virtual MLMT, only travel time and error data (objects touched, path exits) are analyzed. The analysis of trajectory data, collected by the head and eye movement sensors now present in many HMDs, seems to be an under-explored topic for the quantitative and objective study of functional vision. This track raises research questions around the modelling of trajectories, which we also intend to explore in this project [8, 9].

3 OUR RESEARCH PROJECT

Based on these observations, we propose to develop a new adaptation of the MLMT test in VR, respecting the safety of the patients, usable in small spaces with a seated user, and allowing the automated collection of behavioral and attentional data. The test has also been designed to be easy to disseminate, an affordable cost, ergonomic for the patients and the caregivers (ophthalmologists, orthoptists...). This new test can allow:

- A better assessment of the overall impact of the pathology on functional vision;
- Automated recording of attentional and behavioral data (eye movement, head movement, displacement, hand movement) providing information on the mode of exploration of the environment;
- The development of tools to evaluate innovative therapeutic strategies and/or low vision rehabilitation strategies;
- The development of remediation devices.

3.1 Methodology

3.1.1 Virtual environment and material. The main principle of the tests is to follow a path on the floor and destroy objects along the way to make sure they have been detected (Figure 2). As we want to allow the user to sit, we use a torso-steering metaphor for the navigation. The direction of the movement is controlled by the rotation of a rolling chair on which a VR controller is attached, allowing the user to visually explore in all directions while moving in a specific direction (Figure 1). The speed is fixed and was chosen to be quite slow to avoid cybersickness. The user holds a controller in his/her dominant hand to start/stop the navigation by pressing the controller trigger and to destroy objects by touching them with the virtual hand for 2 seconds. Eight equivalent paths have been created. Each contains 17 changes of direction, 8 crossings and 9 objects to destroy. Objects can be placed at different heights and positions on the path to test peripheral vision in different directions. If the user strays too far from the path, navigation is interrupted and the user is informed of the exit by a vibration from the controller. By comparison, the physical MLMT has

11 objects to avoid and 6 floor bars to step over. There are 8 different course configurations, each with the same number of obstacles (9) and turns (17), and there are 6 levels of brightness.



Fig. 1. A subject doing the virtual mobility test.



Fig. 2. Screenshot of the virtual mobility test from the patient point of view.

3.1.2 Data collection. During the experiment, several indicators are automatically collected, such as path exits, objects looked at, objects collided with, head positions and rotations, hand positions and rotations, eye positions and directions. For the final score, path departures, forgotten objects and collisions (defined as contact with an undestroyed object) are counted as errors. This data is aggregated into a score that includes travel time and number of errors.

3.2 Study on visually healthy subjects

A first study was carried out to validate the use of this test in visually healthy subjects, in order to establish a reference database before starting to evaluate this tool in visually impaired subjects. Before each test the subject was asked about: habituation to virtual reality and to video games in general, ophthalmological and general medical history. The pre-tests included measurement of distance and near visual acuity with and without optical correction, assessment of color vision with an Ishihara test, assessment of stereoscopic vision with a Randot test, and measurement with an auto-refractometer. We evaluated this virtual reality mobility test on 42 healthy subjects. The data are currently being analyzed. In terms of tolerability, 4 out of 42 subjects (9.5%) stopped the evaluation early due to cybersickness. However, this must be qualified as the discomfort occurred on average after 8 courses, whereas in practice patients will complete fewer courses in succession.

3.3 Study on visually impaired patients

We are currently starting tests in patients with different types of visual impairment (central, peripheral, mixed). This is a tolerability and feasibility study in patients prior to starting a prospective comparative study between the normal and visually impaired subjects, comparing gold standard measurements of visual function and the measurement of functional vision in virtual reality. At the time of writing this abstract, we have been able to collect the impressions of a patient with a severe form of retinal dystrophy who has tested the virtual maze, and who is used to having evaluations on the real maze (MLMT) available at the CHU of Nantes. He found the concept fun, practical, easy to use and safe. He was able to complete several courses in high light levels, as his condition causes visual difficulties in low light.

3.4 3.4 Project progress and workshop presentation

During the workshop CareIMX, we would like to present the virtual reality mobility test to assess functional vision and the first results in healthy subjects. For the workshop, we could also present the prototype and give demonstrations. In our opinion, this is a very promising assessment tool that could have a place in the assessment of functional vision in visually impaired patients. A future comparative prospective study in visually impaired subjects should confirm this.

4 CONCLUSION

The aim of this study is to develop and evaluate a virtual reality functional vision test for visually impaired patients. Existing functional vision tests have certain limitations in use as we have explained. We have therefore developed a method for assessing functional vision in virtual reality that is equivalent to a mobility test, is available in different lighting conditions, can be used in a consulting room, is safe for the patient, is easy to use for both the patient and the professional, and has the great advantage of collecting a large amount of interaction data that can be modelled and trained. The content of the virtual scene is presented as well as the scientific rationale behind these choices. One of the main contributions of this tool is to place the subject in a seated position, using a torso-steering metaphor for the navigation, allowing both safety and space saving. An initial study was carried out on 42 normal sighting subjects, each of whom completed 12 virtual courses, in order to normalize the tool, obtain tolerance data and a wide range of attention and trajectory

data. A second evaluation phase in patients with different types of visual impairment will confirm the tolerance, reproducibility and discrimination capacity in comparison with the gold standard assessment methods for assessing visual function in visually impaired subjects.

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